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(U.S.) Office of Radiation Programs, Washington, DC

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Environmental Protection
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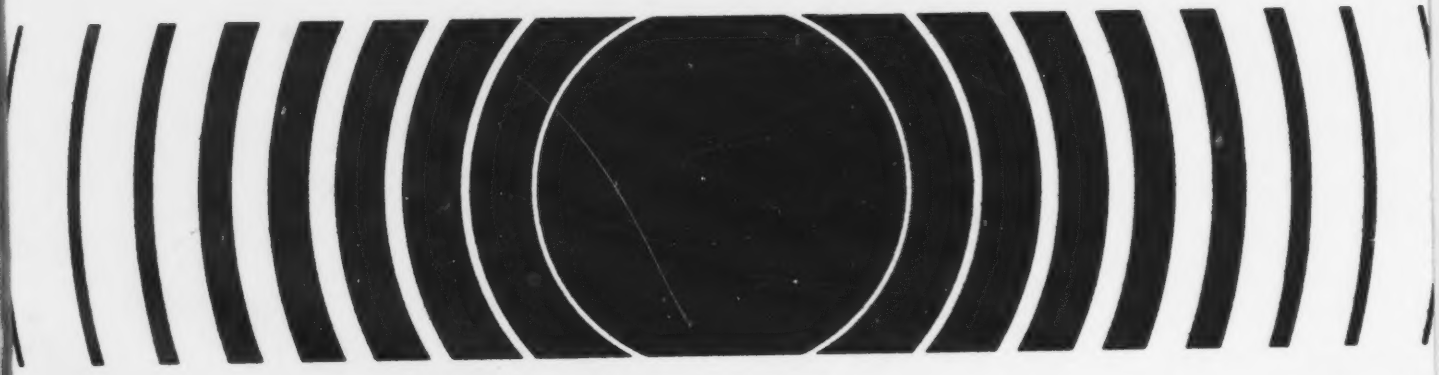
Response to Comments: Guidance on Dose Limits for Persons Exposed to Transuranium Elements In The General Environment



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RESPONSE TO COMMENTS:

GUIDANCE ON DOSE LIMITS FOR PERSONS EXPOSED TO TRANSURANIUM ELEMENTS IN THE GENERAL ENVIRONMENT

October, 1978

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF RADIATION PROGRAMS
CRITERIA AND STANDARDS DIVISION
WASHINGTON, D.C. 20460

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LISTING OF RESPONDENTS TO FEDERAL REGISTER NOTICE

		Date Received
1.	Tenneco Inc.	13 Dec. 1977
2.	Colorado Environmental Health Association	27 Dec. 1977
3.	Timothy E. Wirth, Congress of the United States	4 Jan. 1978
4.	Texas Deptartment of Health	24 Jan. 1978
5.	Ilene Younghein	15 Feb. 1978
6.	N.Y. Federation for Safe Energy	21 Feb. 1978
7.	Natural Resources Defense Council, Inc.	27 Feb. 1978
8.	Edward A. Martell	27 Feb. 1978
9.	Colorado Department of Health	27 Feb. 1978
10.	Jefferson County Health Department	1 Mar. 1978
11.	Department of Defense (Defense Nuclear Agency)	1 Mar. 1978
12.	Nuclear Safety Associates	1 Mar. 1978
13.	Department of Energy	6 Mar. 1978
14.	Conference of Radiation Control Program Directors	7 Mar. 1978
15.	Center for Environmental Research and Development	16 Mar. 1978
16.	Commonwealth Edison (Chicago, Illinois)	24 Mar. 1978
17.	Nuclear Regulatory Commision	24 Mar. 1978
18.	National Council on Radiation Protection and Measurements	27 Mar. 1978

1. INTRODUCTION

The staff of the Office of Radiation Programs has evaluated all comments received in response to publication of the proposed Federal Radiation Protection Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the Environment (Federal Register Vol. 42, No. 230, pages 60956-9, Nov. 30, 1977). Responses to these comments are given in this publication. The Agency concluded that the comments received did not raise substantive new issues and that, therefore, the proposed recommendations should be submitted to the President with only minor changes for promulgation as guidance to all Federal agencies.

Comments and corresponding staff responses have been grouped, insofar as possible, by major subject categories. Responses are given for specific comments as received, and are referred to the text of the Summary Report (EPA Publication 520/4-77-016). In a few instances, comments were very general and not applicable to the proposed Guidance. No staff responses have been provided for these.

New or revised sections for the technical Summary Report document have been prepared on a number of different topics. These follow the Responses to Comments part of this report, and include a section on the costs of remedial actions (based in large part on information provided by the Department of Energy and the Nuclear Regulatory Commission), a revised section on implementation, a discussion of dose rates and risks from soluble transuranium compounds, an assessment of potential health risks to persons outside the boundaries of the Rocky Flats Plant, and a staff analysis of a soil sampling and analysis method proposed by Carl Johnson, M.D., Director of Health, Jefferson County, Colorado.

The comments as received by the Agency are not reproduced here in order to avoid unnecessary duplication. Single copies are available on request from the Director, Criteria and Standards Division, Office of Radiation Programs, ANR-460/CM#2, U. S. Environmental Protection Agency Washington, D. C. 20460.

The Agency has made some minor changes in the wording of the Guidance. The revised text of the recommendations follows this section.

REVISED TEXT OF GUIDANCE RECOMMENDATIONS

In order to assure the protection of persons in the general population by limiting the radiation doses that an individual in a critical segment of the population may receive from concentrations of transuranium elements present above average background levels in the general environment, the following recommendations shall apply for the guidance of Federal agencies:

1. The annual alpha radiation dose rate to members of the critical segment of the exposed population as the result of exposure to transuranium elements in the general environment should not exceed either:
    a. 1 millirad per year to the pulmonary lung, or
    b. 3 millirad per year to the bone.

2. For newly contaminated areas, the Federal agency responsible for implementation should take immediate action to minimize both the residual levels of transuranium elements in the general environment and the radiation exposure of the general public. Determination and implementation of appropriate measures to ensure compliance with the above recommendations should begin as promptly as possible and should be completed within a reasonable period of time.

3. The recommendations are to be used only as radiation protection guidance for presently existing cases of environmental contamination by transuranium elements and for possible future cases of environmental contamination from unplanned releases of transuranium elements. They are not to be used by Federal agencies as limits for planned releases of transuranium elements into the general environment.

DEFINITIONS

"bone" means osseous tissue. The average total weight of this tissue is assumed to be 5000 grams.

"critical segment of the exposed population" means that group of persons within the exposed population who, because of residency or other factors, can on the average be expected to receive the highest lifetime radiation dose to the pulmonary region of the lung or to the bone from a specified source of environmental transuranium element contamination.

"general environment" means the total terrestrial, atmospheric and aquatic environments outside the boundaries of Federally licensed facilities or outside the boundaries of sites which are under the direct control of a Federal agency.

"millirad per year to the bone" means the dose rate attained after 70 years of chronic exposure. This dose rate is calculated by dividing the alpha energy absorbed in the bone during the 70th year by the bone mass.

"millirad per year to the pulmonary lung" means the equilibrium dose rate following chronic inhalation. This dose rate is calculated by dividing the alpha energy absorbed per year in the pulmonary lung by its mass.

"pulmonary lung" means the region of the lung consisting of respiratory bronchioles, alveolar ducts, atria, alveoli, and alveolar sacs. The average total weight of this tissue, including the capillary blood, is assumed to be 570 gms.

"rad" is the unit of absorbed dose, defined as the energy imparted to tissue by ionizing radiation divided by the mass of the tissue. One rad is equal to the absorption of 100 ergs of radiation energy per gram of matter.
1 millirad (mrad) = 10^{-3} rad.

"transuranium elements" means all chemical elements with atomic number greater than that of uranium as classified in the Periodic Table of Elements.

2. RESPONSE TO COMMENTS - SUMMARY REPORT

2.1 Basic Guidance and Standards Philosophy

1. Representative Timothy Wirth

I see a need to question the form of the standards themselves. Currently, the standards are based on the lifetime dose that a person living in the area would receive. It does not look at the community wide effect as a whole. I am not sure that this is the correct approach to take. For example, if the radiation contamination of an area was such that a person living there had one chance in ten thousand of getting cancer, but only fifty people lived in the area, the most likely number of extra cancer cases in the country as a whole would be zero as a result of this contamination. If the same contamination was occurring in Manhattan, there could be thousands of additional cases. The proposed standards do not address that problem. But this is the problem that society faces; not the probability of cancer in a hypothetical person that will result from radioactive contamination, but rather a probable number of cancer cases, depending on the population density of the area. Unless we find cancer in New York less offensive than cancer in New Mexico, we must adjust our standards to take into account these population density differences. The amount of emissions that are acceptable in Manhattan really is lower than in an unpopulated area.

Thus, I think that the EPA should come up with a standard that says "this is the number of probable excess cancer deaths that we are willing to tolerate from a government facility." The actual numerical standards for any site will then be calculated similarly to your current approach, but with the added factor of population.

The advantage of this approach is obvious. It gives citizens in all parts of the country equal protection, since cancer deaths are given the same weight everywhere. It also, by producing varying standards depending on population, presents the government with the proper incentives when it looks at where to locate such facilities. And finally, it automatically will require the appropriate tightening of standards as population around any existing facility increases.

Staff Response - Two separate points must be addressed in response to this comment, namely the adequacy of the recommendations with respect to the individual and also the social and economic implications of the exposure of large population groups.

The guidance recommendations as stated are designed to limit the risk to an individual in a critical segment of the population, independent of other considerations. Such a limit provides equal public health protection to citizens in all parts of the country. The numerical risk limit as proposed is not intended to be viewed as an acceptable limit, but rather is to be interpreted as recommending that doses to individuals should be kept well below the limit and that exceeding the guidance values is unacceptable. The maximum risk to an individual from lifetime exposure to transuranium element contamination was proposed on the basis of comparisons with other commonly accepted low probability risks. The appropriateness of such a proposed risk limit is a subject for social judgment.

Cumulative risks to a large population group were also considered in the development of the guidance but, because the estimated population dose commitments for all existing sites were small, the guidance recommendations were based on the maximum risk to individuals. The observation that population impacts should be considered in the decision making process is a valid one. However, if one were to limit the total adverse impact at any site to a given number of fatalities independent of the population density, then the guidance would not provide equal protection to persons in all sections of the country. The Agency has taken this into consideration in its recommendations concerning future contamination, where it recommends that remedial action be carried out as soon as possible after occurrence to a level as low as reasonably achievable and with the numerical guide as an upper limit. The determination of a level as low as reasonably achievable would take into account the size of the population exposed, the cumulative population dose as well as the costs of cleanup. Therefore, both the individual and population risk are integral to the implementation of this guidance. In effect, therefore, the projected impact of a source in terms of committed population dose or potential fatalities becomes the primary consideration in determining the range and scope of remedial actions within the constraint of assuring that individual dose rates not exceed the guidance recommendations.

2. Department of Energy

1. "It is instructive to compare the proposed EPA Guidance limits with...(those)... recommended by other bodies...On the basis of these comparisons the EPA proposed guidance could be considered to be unnecessarily restrictive."

Staff Response - The comment compares the proposed guides to upper limiting doses for the general population from all sources combined as recommended by ICRP, FRC, and NCRP. These groups all emphasized that the recommended limits were upper bounds; that within these, doses should be permitted only insofar as they could be justified and were, in addition,..... as low as practicable or as low as reasonably achievable. Too often these recommended limits have been treated as defining the acceptable range of exposure, (e.g. like speed limits) and this comment falls into the same error. The proposed EPA guides represent instead a judgment of what exposure, within these bounds, is acceptable because it adequately limits the risk to a critical segment of the population and is economically achievable. Disagreement with the proposed guides should be based upon the validity of EPA judgements on these latter two points, not on the difference between the proposed guides and the limiting recommendations of ICRP, FRC and NCRP.

3. Department of Energy

"The EPA apparently adopts the position that the total permissible radiation exposure should not be allocated to a single source or activity. The ICRP, however, considers it quite appropriate ...If the EPA has embarked upon a policy of apportionment...This should be clearly presented..."

Staff Response - EPA does not take the position that the general dose limits are available for apportionment. Neither does the ICRP; they endorse instead optimization of dose reduction from individual sources, irrespective of contributions from other sources (para. 121, ICRP-26). Since the exposures governed by the proposed guidance are likely to be chronic, the even more restrictive considerations of para. 122 and para. 123 of ICRP-26 define ICRP's view of suitable boundary conditions on dose (100 mrem/yr) from all sources. The question of apportionment is not germane to choosing an optimized dose level for radiation protection; it is only pertinent to situations in which several relatively large doses may accrue to a single individual from separate sources. That situation does not appear pertinent to the doses contemplated as acceptable by the proposed guidance.

4. Conference of Radiation Control Program Directors

"..it is hoped that EPA will appropriately address the impact of this standards and guidance on the apportioning of the 170 mrem/year limit, or its reduced value."

Staff Response - EPA will address this matter when and if it appears to be a realistic problem. At this point in time, it appears highly improbable that the 4 mrem/yr drinking water limit, the 25 mrem/yr uranium fuel cycle limit and the present proposed guides could result in combined doses to a real individual's organs which even approach the sum of these three limits, let alone the 170 mrem/year bound or any foreseeable future reduction of that limit.

5. Department of Energy

It is not clear how this Guidance will "offer much greater protection to the vast majority of the population at lesser risk." This vast majority receives no protection nor does it require any. (p-15, lines 20-24)

Staff Response - We do not agree. The proposed guidance establishes recommendations on an upper limit for exposures to the critical segment of the population by transuranium elements in the general environment. By ensuring compliance with these recommendations, an upper level of risk is established. Because most members of the general population are exposed to lower doses than the defined "critical segment," the vast majority of the population is at lower risk and afforded greater protection.

6. Department of Energy

It would be useful to describe and document the "...different regulatory requirements, constraints associated with remedial actions for a particular carcinogen, uncertainties in the calculations, differences in methods used to derive lifetime risks, and economic considerations." This would enable the user of this Guidance to understand the basis for and the considerations involved in this Guidance. (p-16, lines 18-22)

Staff Response - The content and basis of Federal actions intended to regulate carcinogens are generally published in the Federal Register. Because no common basis presently exists for risk evaluations, and there is no agreement on a level of "acceptable risk" applicable to all situations, such comparisons do not serve a useful function. As stated in the rationale for the Guidance, there is a real distinction between actions intended to achieve a remedial rather than preventive objective. The best comparison available is with the contamination of the James River with kepone, but the health and economic impacts of the two situations are so different that the decisions made for kepone cannot be applied directly to transuranium element contamination. The public health risks associated with the transuranium guidance recommendations are generally lower than those for most other regulated carcinogens.

7. Department of Energy

The sentence on page 16 makes the very important point that the Guidance is "applicable to remedial and restorative actions, and must be distinguished from risk levels which provide for a routine level of acceptability;" but this distinction does not seem to have been applied in the derivation of the Guidance.

Staff Response - The statement is intended to convey the idea that the level of an "acceptable" risk is generally lower for a preventive than for a restorative situation. The Agency has not evaluated the factors which determine the appropriate level of risk for routine and planned releases.

8. Department of Energy

Since dose limits are customarily expressed in units of rem, it seems unusual to find them expressed here in rad. While an effort is made to justify this in Annex III, many readers may never get to Annex III and it might be well to show the rem equivalents. If this is done, the limits become 10 mrem/y to lung and 150 mrem/y to bone. On such a basis the limit to lung seems much more conservative than the limit to bone. This may be justified, in part, by the more complete information on human bone risk, as discussed in Annex III. (page 21, lines 3-4)

Staff Response - The rad is the basic unit of absorbed dose for ionizing radiation, while the rem is a relative unit which modifies the rad by the "relative biological effectiveness" for the specific type of radiation. Dose limits are best expressed in rad in order to avoid the ambiguity introduced by controversy on the "quality factor" for alpha radiation in different tissues (see ICRP Publication 26). In the development of this Guidance, the comparability of dose rates to different organs is based on risk.

9. Tenneco Inc.

Shouldn't the absorbed dose be given in terms of the SI derived unit, the becquerel (Bq)? Similarly, the absorbed dose rate unit should be in grays per second (Gys/s).

Staff Response - The Federal Register notice 42:206 pp 56513-4, published by the Department of Commerce, which defines policy regarding use of metric units in the United States, states that "in those cases where their usage is already well established, the use, for a limited time, of the units (...curie, roentgen, rad) is accepted, subject to future review."

10. Ilene Younghein

Much is said in your assessments about economics and practicality but nothing about suffering. There is the suffering of parents with abnormal children, the suffering of men, women, children and animals dying of lung, bone and kidney cancer.

Staff Response - Suffering cannot generally be quantified in monetary terms, but is certainly considered with respect to genetic defects and cancer mortality. The rationale for the guidance is not based on any criteria related to the direct or indirect monetary costs of a human life or to suffering and only uses economic analyses to the extent necessary to show that compliance is feasible.

11. Ilene Younghein

Let me comment on the report itself. One, it is nameless-therefore blameless. It appears to be a whitewash, in trying to live with the mess we already have, and it certainly doesn't accurately access your previous hearings. Most of the reports are either middle of the road or downplay the dangers of plutonium. Reports by such scientists as Samuel Milham, Thomas Mancuso, Irvin Bross, Karl Morgan, John Gofman and Arthur Tamplin were not included. Edward Martell, who has done extensive research or problems with plutonium at Rocky Flats, didn't make the list either. I always want to know who writes the reports, their positions, and possible conflicts of interests.

Staff Response - The proposed Guidance was prepared by the staff of the Office of Radiation Programs and published after review by the Administrator of EPA. It therefore represents an Agency viewpoint rather than that of individuals.

The Agency staff is thoroughly familiar with the published reports of the scientists named and has considered their results in preparation of the Guidance to the extent appropriate.

12. Ilene Younghein

In Annex 1, p.9 you say "large areas outside the exclusion areas have become contaminated with plutonium". Compared to the age of the earth, the last thirty years would be similar to a grain of sand on a beach. At the risk of discussing ethics, I find it highly immoral that in the last few years we have permanently contaminated portions of this earth - something that hasn't happened in the billions of years previously. Is this being weighed in your radiation standards and your environmental impact statements?

Staff Response - No. The ethical aspects of releases of transuranium elements to the environment were not considered in developing the guidance recommendations.

13. Jefferson County Health Department

I am concerned with the criteria on page 60957 in the first paragraph, Rationale for Guidance. One of two primary criteria used in developing this guidance, "That any actions required by implementation of the guidance be practical in terms of overall economic requirements". In view of the nature of the guidance proposed, I feel that economic concerns have really been given foremost consideration, perhaps with intent to minimize any economic impact on federal agencies or private corporations which have contaminated offsite lands. It appears to me that the concern for the public health has been given lower priority here.

Staff Response - The order of application of the criteria has been reversed in this comment. The risk to an individual in the critical segment of the population is the primary concern of the guidance. Implementation was deemed to be practical in terms of overall economic requirements.

14. Jefferson County Health Department

I feel that the estimates in this proposed guidance of deaths due to cancer, the effects on longevity, and the genetic effects cannot be conservative estimates. As an illustration of the present federal non-conservative policy in regulating radiation exposure, consider the recent report of a significant increase in chromosome abnormalities in plutonium (workers) permitted by federal radiation protection guides. The current radiation protection guides are simply too high to provide adequate protection. I disagree with the report in that "realistic" estimates must be made where there is insufficient knowledge. Our experience with radiation hazards over the past fifty years should teach us that we must be prudent in evaluating radiation hazards and that we must be conservative in establishing radiation protection guides.

Staff Response - The Agency staff's estimates of the relationship between radiation dose and cancer mortality and serious genetic effects are not intended to be conservative but rather to be realistic estimates based on best available data. The degree of conservatism can only be established by comparison with such realistic estimates, and is here based on introducing an "adequate margin of safety" in the recommended dose rate limit for the "critical segment of the population". On the basis of public comments received by the Agency, we believe the judgment with respect to the dose rate limit and associated maximum risk to an individual to be reasonable.

The staff does not believe that previous Federal Guidance on occupational expsoure has a bearing on guidance levels for transuranium elements in the general environment.

2.2 Risk Associated with Guidance

1. Department of Energy

The dose limits of the Proposed Guidance are as low as they are for several reasons. The EPA assumed an acceptable level of risk of slightly less than 10^{-6} per year. The ICRP (Publication 26) assumed an acceptable level of risk in the range of 10^{-5} to 10^{-6} per year, and established its "individual member of the public" limit at a level estimated to be equivalent to a risk of 5×10^{-5} per year, assuming that the average exposure will not exceed 10% of the limit. This single factor of about 50 is enhanced in the case of lung by an EPA factor relating lung dose and cancer risk that is larger than the corresponding ICRP factor, but is largely cancelled in the case of bone by an EPA dose-risk factor smaller than the ICRP factor.

Staff Response - EPA has not assumed an "acceptable" level of risk. The Agency recognizes that the stated level of unacceptable risk, i.e. greater than 10^{-6} per year, is about the same as the lowest value given in ICRP Publication 26, and that there are some differences in factors assigned to risk conversions from those reported in ICRP-26. In view of the fact that the ICRP system of dose limits applies to the doses received from a variety of sources, and not a single source such as dealt with by EPA, the differences are considered reasonable for the environmental problems currently faced.

2. Conference of Radiation Control Program Directors

The text of the proposed guidance was developed using widely accepted procedures in ascertaining radiation doses and dose rates and the related health risk. The level of acceptable risk has been used before; however, not to the extent used in this document. The level of risk deemed acceptable by EPA in this guidance appears to be arbitrary in view of the levels of transuranics in the general environment. Stronger wording than that provided in the text of the guidance must be provided to the effect that the "levels must be as low as reasonably achievable with available technology". This would provide for the use of lower level standards where the situation would allow, i.e. Colorado. It is also a reasonably conservative approach for the implementation of the guidance as it is finally adopted.

Staff Response - The EPA staff has not assumed an "acceptable" level of risk. The recommended maximum risk of 10^{-6} is judged by the Agency to be such that any risk significantly greater would be unwarranted and therefore unacceptable. Such determinations must rely on judgments, since no means exist for deriving an "acceptable" level of risk for non-threshold pollutants. The Agency does not believe that the stated level of risk is large; it is certainly comparable with risks associated with many other pollutants and food additives which are believed to be carcinogenic. In practice, it is anticipated that no person will be exposed to the limiting risk but that exposures will be at levels substantially lower, even for those few individuals in the critical segment of the population.

3. National Council on Radiation Protection and Measurements

The derivation of the risk values used in setting these limits is poorly explained. Comparison is made between real risks that involve large numbers of people with hypothetical risks that involve only a small part of the population.

We recommend that the derivation of this risk of 10×10^{-5} per lifetime be reexamined and justified on the basis of the population size, uncertainty in the value, economic costs, environmental costs, and human costs.

Staff Response - The Agency staff has not made a distinction between "real" risks and "hypothetical" risks. The population dose has not been used as a rationale for the guidance levels; rather, the guidance levels were based on judgment with respect to the level of risks to individuals.

The factors suggested in this comment have been considered with respect to the lifetime risk associated with the guidance levels. Population size is not included because risk takers (with respect to this guidance) can be individually identified and the Agency has the responsibility of protecting these individuals. Uncertainties in risk estimates are recognized, but they were not judged so large as to prevent the issuance of guidance. Costs (economic, environmental and human) were not directly part of the guidance rationale, but were considered to the extent necessary to show that the guidance could be implemented.

4. Colorado Department of Health

While the risk associated with proposed guidance appeared to be well below other risks experienced by the general population as depicted by Annex IV, if the situation can be controlled then this must be done, i.e., as low as reasonably achievable by available technology. Therefore, if the State of Colorado can justify that their more conservative standard is reasonable for the situation that currently exists within the State, then that standard or lower achievable levels must be applied. Depending on the method of comparison, the current Colorado standard for Plutonium-in-Soil is a factor of 70 + to 150 times lower or more conservative than the proposed EPA guidance.

Staff Response - EPA believes that the practice of reducing exposure to levels "as low as reasonably achievable" in accord with the long existing practice in radiation protection has merit and is to be encouraged. The State of Colorado may be able to establish more stringent requirements than Federal Guidance if it so desires. Federal guidance is only directed to the Federal agencies and their programs to assure the health and safety of the public.

Comparisons between the Federal Guidance and the Colorado standard are inappropriate because they have an entirely different objective and specify different implementation procedures. The Colorado standard is intended to protect construction workers and sets a plutonium soil concentration level which, if exceeded, requires that special protective actions be considered. The Federal Guidance, on the other hand, designates a dose rate to persons in the general population which serves as a limit for exposure to transuranium elements in the general environment. The Colorado standard and the Federal Radiation Guidance therefore can be viewed as complementary and serving different purposes.

5. Center for Environmental Research and Development

I urge you to publicize widely what exactly it is you are proposing. You are proposing to allow polluters to ignore alpha activity below 4400 dpm/100 cm^2 background in all the situations described in EPA 520/4-77-016. However, you present considerable evidence that background is 40 dmp/100 cm^2 or perhaps 4 dmp/100 cm^2 (for example, pags. 3, 5; Annex 1, pgs. 3, 4, 5). Thus the contamination you are proposing to allow is higher than background by a factor of from 100 to 1000. On the face of it, terming such levels of contamination "acceptable" is a travesty of environmental protection.

Staff Response - The agency staff does not believe that the level of pollution from previous contaminating events is a proper basis for setting standards. It has established its guidance on the basis of risk and dose and not on the basis of a fraction or multiple of background caused by the testing of nuclear devices. Reference to such background levels are useful in terms a perspective on the level of environmental contamination but are not useful in setting national guides based on health protection. The Agency does not agree that the guidance recommendations are "a travesty of environmental protection" but rather views its guidance as health protection requirements that should not be exceeded.

6. Tenneco

I agree with the concept of looking at acceptable risk rather than taking the approach that no exposure is to be allowed because someone may contract a disease and die. I personally believe that such "lowest feasible level" controls are doomed to extinction because of the realities of life. There are finite risks associated with all human endeavors. Cigarette smokers and seat belt non-users certainly seem to comfirm that people are willing to accept risks. I should hope that statutory standards consider the "big picture" when levels are set that may become infeasible due to real economic considerations.

Staff Response - The agency staff agrees with this comment, to the extent of recognizing that mandating of a zero risk concept is inappropriate and not feasible. However, it believes that government has an obligation to its citizens to provide maximum protection of health, safety, and welfare within the constraints of economic and social considerations.

7. Jefferson County Health Department

In the second paragraph under Rationale for Guidance, reference is made to the exposure of all persons to "a large number of competing risks", which implies somehow that because of other risks to health that the risk of health from radiation is made somehow acceptable.

I believe that the expression "competing risk" is used inappropriately on page fifteen (2nd paragraph) and elsewhere. The use of the expression here implies that radiation exposure is not very important because of other "competing risk". I think we must consider all risks to health as additive or perhaps potentiating rather than "competing" i.e., asbestos workers and uranium miners who also smoke cigarettes have much more severe effects than merely adding risk factors together. The term "competing risks" implies that one adverse effect somehow ameliorates another adverse effect.

Staff Response - The comment misinterprets the use of the term "competing risks" if it implies that this has been used to make the radiation risk acceptable. The term "competing risks", as used here, expresses the fact that all persons are continuously subjected to a large number of risks that compete for the deaths of all individuals. The removal of any one of these competing risks (e.g. heart disease) results in an increased risk of death from other causes of death. The introduction of a new cause of death (e.g. exposure to transuranium elements) reduces the number of deaths from other causes, but at the same time other causes of death will take the lives of some of the individuals otherwise destined to die of the new cause of death (in this case, exposure to transuranium elements), thereby reducing its apparent risk. The intent of the calculation of competing risk is to give the reader some perspective on the magnitude of the additional risk of death to an individual from exposure to transuranium elements at the guidance limit.

8. Jefferson County Health Department

It must be noted that the proposed annual alpha radiation dose rate to the public living in such contaminated areas (one millirad per year to the pulmonary lung or three millirad per year to bone) will result, on the basis of animal studies, in 20 millirem to lung, 960 millirem to trachiobronchial lymph nodes, 60 millirem to bone, 20 millirem to liver, 4 millirem to the kidney and one millirem to gonads. These may be contrasted with the radiation dosage limits established by the 1976 EPA Water Regulations which limit the exposure of the general public to no more than 4 millirem per year from "man-made beta and photon emitters". A millirem is a term developed to consider biological effectiveness and organ distribution of different types of radiation, and make them comparable in terms of health effects. As you can see there is a marked discrepancy between the proposed guidance levels and the regulations promulgated last year.

I am puzzled at the non-conservative guidance proposed by the EPA. I thought the maximum radiation levels established by the EPA Water Regulations were commendable and well-supported, and reflected concern for public health. This is not true of the proposed guidelines.

Staff Response - The basis and rationale of the EPA Drinking Water Regulations and the Guidance for Transuranium Elements are entirely different and not comparable. The four millirem annual limit in the Drinking Water Regulations is given as the maximum contaminant level only for man-made beta and photon-emitters in finished drinking water. The biological risk from alpha emitters differs markedly, so that a direct comparison in terms of absorbed dose is not appropriate. The Drinking Water Regulations specify a limit of 15 pCi/liter of gross alpha contamination which, at an intake of 2 liters/day, is equal to 1.1×10^4 pCi/year. For soluble transuranium elements, where a transfer fraction of 1×10^{-3} is conservatively assumed, this intake can be equated to about 0.5 mrad/year to bone. Noting the fact that drinking water represents a single ingestion pathway while the proposed guides refer to food, water, and inhalation, the limiting dose rates for the Drinking Water Regulation and the Guidance for Transuranium Elements are comparable with respect to the risk to the individual.

9. Jefferson County Health Department

I disagree with the third paragraph under Rationale for Guidance, in that I believe the estimated risk is understated, that is, in my opinion considerably more than a hundred cases of cancer per million would occur as a result of exposure to the proposed guidance level. The guidance acknowledges this in part by saying "It must be recognized that these estimates are not precise, and have an uncertainty of at least a factor of three for cancer risks". I believe we must allow for these "uncertainty factors" and establish lower guidance levels than have been proposed. In the first paragraph on page 60958 the guidance states "Additional risks may result from translocation of a small fraction of the transuranium elements in the lung to other body organs, especially to the liver and bone". Research with animals indicates that much more than a "small fraction" of plutonium retained in the lung is translocated to the bone. In the same paragraph, reference is made to hypothetical cohort of 100,000 persons receiving an annual average dose rate to pulmonary tissue of one millirad per year per person, which could potentially result in ten premature cancer deaths, or a hundred premature cancer deaths per million. Birth defects and general adverse effects on health due to chromosomal damage must also be considered.

The proposed guidance level of 3 millirads to bone is estimated to "potentially result in less than six premature deaths from such cancers per 100,000" (or 60 deaths per million). However, this estimate is particulary controversial since estimates of such effects vary widely. In the third paragraph on this page, concerning genetic damage, the guidance states that at the guidance level dose to 20 genetic defects would be produced per 100,000 live births (10 to 200 genetic defects per million) in the first generation. However, we must also consider the cumulative genetic defects produced for all generations as a result of such an exposure. The fact that there already is a significant rate of genetic defects does not make an additional increment more acceptable.

Staff Response - The rationale for the guidance is based on the staff's technical evaluations. The numerical estimates of lifetime risk represent best judgments with a stated range of estimated uncertainty. Additional risks resulting from translocation to other organs, including bone, were included in the total risk to an individual. First generation and subsequent generation genetic risks for continuing exposure of both parents at the guidance limits are given in the technical documents. The staff does not believe that risk estimates have been underestimated.

The guidance rationale considered serious genetic effects as expressed within ten generations from the individual exposure; all of the additional future generations do not add significant numbers serious genetic effects in comparison. The agency has not and cannot make a judgment with respect to an "acceptable" rate of serious genetic effects that would be committed by the guidance recommendations.

10. Jefferson County Health Department

It seems quite likely that releases of radioactive materials from the plant have already made some measurable impact on the health of populations so exposed. An examination of death certificates of residents dying in 1975 in eight census tracts in south end of the county, showed a significant increase in deaths from leukemia in the areas near the plant site. In addition, examination of death certificates shows an increase in age-specific death rates from lung cancer. Estimates of risk to health have been published in the Proceedings of the IVth International Congress of the International Radiation Protection Association.

Staff Response - The agency staff does not believe that epidemiological studies have shown an increase in risk to individuals living in the vicinity of the Rocky Flats Plant. See comment 11 in Section 3.3

11. Jefferson County Health Department

I am puzzled that the risk of the proposed guidance level (page 15) was less than one chance per million per year, and less than ten per hundred thousand per lifetime. Why not be consistent and say, "less than one chance per million per year and less than one hundred per million in a lifetime?" It is obvious that these risk estimates are not precise, and for that reason I would prefer to see a range of risk estimates given as has been customary in the literature.

Staff Response - The lifetime risk of death by specific cause for members of a cohort is generally given in numbers per hundred thousand. The annual risk for an individual can be given in any desired unit -- number per million was chosen to avoid values less than one. An estimate of the range of uncertainty is provided.

12. Nuclear Safety Associates

It is recommended that the EPA examine the regulations and practices of other Federal Agencies to determine permitted levels of public health risk associated with carcinogens and other hazardous substances the other agencies regulate. The findings should be considered in the interpretation of dose limits associated with transuranium elements in the environment.

It is recommended that regulatory limits which the Agency may develop for transuranium in the environment be consistent in associated public risks with regulatory limits for other non-radioactive substances in the environment that the Agency regulates.

The supporting document does not reflect the broad perspective needed to promote consistency and reduce the misapplication of resources.

Staff Response - The Agency recognizes that consistency in regulatory actions based on a limiting risk to individuals or population groups is both desirable and necessary. However, the societal judgment on level of acceptable risk for the many known and/or suspected carcinogens differs greatly and is based largely on the perceived balancing of costs and benefits for each material or situation. The decision-making process must recognize these differences. Therefore, consistency in regulatory actions does not necessarily require same numerical risk limit for each carcinogen, but rather a consideration of the level of risk acceptable to society.

13. Department of Energy

It would be helpful if the terms "risk level" and "cancer risk" were clarified. Cancer risk could refer to (a) contracting a cancer of any kind, (b) dying of cancer, or (c) something else. (p-16)

Staff Response - All of the numerical risk estimates are for cancer mortality. The difference between mortality and cancer incidence is not significant for the cancers considered.

14. Department of Energy

Justification of the risk level chosen is not adequate and provides no convincing comparisons with other risks of life, particularly those risks which involve a comparatively few people. The examples of saccharin and kepone seem inappropriate because a much larger population is involved. (p-16)

Staff Response - As evidenced by the comments received by the Agency, it is probably impossible to choose a single level of risk, or to provide a justification for a chosen level, which is acceptable to all persons in a given population. Such decisions represent a social judgment and cannot be made solely by a regulatory agency. The principal rationale for the guidance value is that adequate protection be provided to individuals in a critical segment of the population and that all other persons be at a smaller risk. Comparisons with other risks to life, while not exactly equivalent, are the best available. See also response to comment 12.

15. Department of Defense

Risk Perspectives: This entire section takes liberties with the true situation. The estimation of risk is based on data obtained at high dose rates extrapolated to low-level conditions and has many assumptions. This should be stated initially and then followed with what EPA has determined to be the risk. The succeeding annex can go into detail. (p-24)

Staff Response - The views of the staff with respect to the linear, non-threshold hypothesis of risk from radiation are analogous to those of the National Committee on Radiological Protection and Measurements (NCRP) and of the International Commission on Radiation Protection (ICRP).

16. Department of Energy

The limits specified seem excessively conservative, in particular, the limit for lung. If 25 mrem per year is acceptable for critical populations exposed to releases from uranium fuel cycle facilities (40 CFR 190), it does not seem reasonable to restrict lung exposure from environmental transuranics to 10 mrem (1 mrad). In fact, an exposure limit considerably higher than the 40 CFR 190 limit would seem reasonable in view of the lesser probability of exposure to transuranics, and the smaller populations likely to be so exposed. (p-21, lines 3-4)

Staff Response - The intent of the Agency is to reduce all radiation exposures to levels as low as practicable. For the uranium fuel cycle standard, this was done by considering the cost of reducing risks. For the proposed plutonium guidance, the limit is based on an Agency judgment with respect to what would be an unacceptable level of risk to an individual. It is not appropriate to compare standards or guides based on such different rationales.

17. Department of Energy

This section should be prefaced by a statement emphasizing the highly uncertain, and probably maximizing, assumptions involved in extrapolating radiation risk estimates derived from data obtained at high dose levels to the very low dose levels considered in this guidance. This point is now made very inconspicuously in a phrase attached to an unrelated sentence near the end of this section (p. 27, line 23).

Staff Response - We agree that there is an uncertainty associated with risk assumptions, but do not agree that the assumptions necessarily maximize the estimated risk

18. Department of Energy

This description of risk applies to very insoluble $^{239}PuO_2$ and not, as stated, to transuranics generally. (p-25, lines 4-16)

Staff Response - The risks are related to dose rates for the specified organs and are applicable to all alpha emitting radionuclides.

19. Ilene Younghein

Comparing death rates from plutonium to those from chicken pox, snake bites and saccharin is pure hype. Society is not necessarily locked into chicken pox or saccharin or rattlesnakes for thousands of years hence. The risks from saccharin could stop tomorrow, but with the terribly toxic transuranics, there is no way of stopping its deadly emissions. The same particle of plutonium that might kill me could also kill another poor soul in the year 2978.

Staff Response - The data were provided to give some understanding of the comparative risks involved in terms of present day human diseases and activities.

20. Ilene Younghein

The proposed standards of 1 millirad to lung tissue and 3 millirad to bone seem high to me in light of the persistent nature of the transuranics in the environment-especially plutonium 239.

Staff Response - The comment on the proposed risk level is acknowledged.

21. Ilene Younghein

Transuranic elements accumulate in the environment from fallout, accidents, and releases from nuclear facilities. I find Table A 1-3 worrisome. Cumulative deposits went from 0 (uCi/m^2) in the early 40s to 0.00007 (uCi/m^2) in 1954 and built up to almost 0.003 microcuries per square meter of plutonium 239 in N.Y. City in 1975. It seems that every time it rains it rains radiation from heaven. Whether that radiation comes from Russian or Chinese or Indian or our bomb testing, or our abortive satellite that broke up over the Indian Ocean and released over two pounds of Pu-238 to the atmosphere, or the recent Soviet mishaps that sent their satellite down in Canada, spewing debris and eventually fallout. Add to that the fires and releases from Rocky Flats, the leaks of Pu at Mound Labs and Hanford, the buildup of plutonium along the coast near the Windscale Plant in England and the leaking drums off the coast of San Francisco, the contaminated islands of the South Pacific, the accidents and material unaccounted for at Apollo and at Crescent and you have a sobering picture, indeed. How can we safety handle increasing amounts of the transuranium elements when we have done such a miserable job so far?

Staff Response - The question is philosophical and beyond the scope of the guidance. The intent of the guidance is to assure protection of public health from existing and future transuranium element contamination.

22. Ilene Younghein

Your charts on the death rates from plutonium are not as clear as the one you did on Background Radiation on page 9. You have divided your statistics between Pu-239, and transuranium elements, lung, liver and bone cancer, inhaled and ingested plutonium, so it is hard, if not impossible to compare the statistics on plutonium and the transuranics of the 1 millirad to lungs and 3 millrad to bone, with your charts on background radiation. What is the expected death rate from all causes on the inhalation and ingestion of transuranium elements per 100,000 people at the dose allowable by your proposed standards. If the environment becomes contaminated to your allowable levels, how many deaths do you project over the radioactive life of these elements-about 250,000 years for Pu 239? With the projected increase in nuclear plants, breeder reactors, reprocessing, and the proliferation of nuclear power and weapons worldwide, the levels of plutonium in the environment will be increasing steadily. Allowable releases may be small, but the effects of accidents or raising levels of contamination cannot be dismissed.

Staff Response - The consequences considered in risk evaluations for the guidance include all types of cancer or incidence of serious genetic defects. The risk levels as stated are for lifetime exposure of an individual at the maximum dose rate. It is deemed very unlikely that the entire country could become contaminated to the guidance limits, and it is not possible to project cumulative population impacts over 250,000 years because of the very considerable uncertainties involved. Evidence to date indicates that the plutonium deposited on the soil sufaces becomes less available for uptake by man with time. Long-term projections in terms of geological time scales are inappropriate and of little use.

23. Ilene Younghein

According to the Tri-State radiation study conducted at the Roswell Cancer Institute in Buffalo, N.Y., radiation can cause health effects other than cancers, such as asthma, allergies and other health problems. There may be risks from plutonium in other categories than genetic and carcinogens.

Staff Response - The results quoted are largely speculative and not supported by adequate analyses. The risks discussed in the technical summary documents are those for which a reasonable correlation can be established.

24. Ilene Younghein

The statement in section 3.2 p.27 "therefore, the calculated risks may be overstated, and no deaths from exposure to transuranium elements in the environment have been identified" is irresponsible. Edward Gleason, a trucker, died after his arm became contaminated with plutonium spilled from a container. Workers at Harford and Rocky Flats show a higher than normal incidence of cancer and leukemia. Cancer rates in this country have been climbing at a rate of 2.2% a year. Could not a percentage of these cancers be due to the buildup of plutonium in our air, soil and water? (p-27)

Staff Response - The statement in Section 3.2 refers only to risks to the general population from existing contamination levels, makes no reference to occupational exposures, and is believed to be an accurate evaluation of the situation as of today. If the linear non-threshold hypothesis of radiation damage were carried to the extremely low levels resulting from worldwide fallout, one to two additional deaths per year on a statistical basis would be predicted for the entire U.S. population from this cause. Such small variations cannot be detected or verified, and would represent an infinitesimally small fraction of all cancer deaths.

25. Nuclear Safety Associates

Interpretation of the maximally acceptable risk imposed on a member of the public is essential to the selection of dose limits stated in the proposed guidance. Yet the supporting document, EPA 520/4-77-16, reflects superficial consideration of risk acceptability and therefore inadequate support for the proposed dose limits. For example, the only comparison with other EPA guidance was a mention of the cancer risk associated with the action level for kepone in fish (no mention of non-carcinogenic effects on health). The only comparison with another Federal agency was an FDA risk estimate for saccharin consumption and a definition of a lifetime risk of one per million as "virtually safe." Only a few of the risks of death experienced in the US population as a result of other causes were presented for comparison with the risks associated with the chosen dose rate limits for TRU; by comparison, the estimated risk associated with the dose rate limits for TRU is low. It is thus evident that support for the selection of a maximum acceptable risk to a member of the public was inadequate, or, at least, inadequately documented. It is recommended that firm bases interpreting the maximum acceptable risk be developed before corresponding dose limits are selected.

In view of the relevance which the EPA purported to attach to uniformity and overall perspective in the determination of a maximum acceptable risk to a member of the public, it seems reasonable to request that EPA demonstrate adherence to that philosophy in this proceeding.

Staff Response -*See* response to comment 14.

26. Colorado Environmental Health Association

Johnson (1977) in a paper presented to the Annual American Public Health Association has reported increased leukemia death rates in the eight census tracts nearest Rocky Flats as compared to nineteen census tracts located in southern Jefferson County. These death rates range from 2 to 3 times the rates from southern Jefferson County. The census tracts nearest Rocky Flats range from 3 to 33 mCi/km^2 or 0.003 to 0.033 uCi/m^2 in plutonium contamination of the soil. The proposed guideline of 0.2 uCi/m^2 is from 6 to 66 times the level associated with increased leukemia rates according to the study.

Staff Response - The agency has not accepted Dr. Johnson's report as a valid epidemiological study. See response to comments 10 and 11 in Section 3.3

2.3 Economic Cost Associated with the Guidance

1. Department of Defense

Is $500 the cost for estimating the cost to do restorative actions or is it the cost for doing restoration as implied in Annex VI? (p-17, line 17)

Staff Response - $500 is stated as the minimum cost for remedial actions. (see also response to comment 4).

2. Department of Defense

There is no basis for concluding that costs of implementing the guidance at the reference level would be reasonable and achievable, particularly in view of proceeding discussion concerning the fact that costs vary "by location, contamination level, and other factors" and "...that there are large uncertainties associated with both the areas involved and in the estimates of costs." This whole presentation is subjective if not speculative and in a document of this type, objectivity and specificity should prevail. (p-18, line 7)

Staff Response - The costs of implementing the guidance have been reviewed and are disscussed in Section 4. (see also response to comment 6).

3. Department of Energy

It is not clear what "changes by factor of ten" refers to; certainly not to the precision of the calculations, which seems to be implied. Some of the factors involved in the calculation of cost estimates may be uncertain by a factor of ten, but the cost estimates should be much better than the basis on which the Guidance itself is established. This should be clarified. (p-17, lines 10-12)

Staff Response - The statement refers to soil contamination levels. We do not understand the meaning of the comment "cost estimates should be much better than the basis on which the Guidance itself is established."

4. Department of Energy

This sentence is not clear. It reads as if $500 per acre is the cost of just estimating costs associated with remedial action. This might very well be true, but is not the meaning intended. A total cost for remedial action of $500 per acre is such an unrealistically low estimate as to be grossly misleading. It includes only the monetary costs of the simplest cleanup options, with no consideration of environmental costs, societal costs or cleanup risks. Certainly it cannot be reasonably assumed that a "minimum cost" will be applicable to all (or even any) areas which might require cleanup. (p-17, line 17-19)

Staff Response - The purpose of introducing a minimum cost estimate of $500 per acre appears to be misunderstood in this comment. The intent of the staff was to show that, even for such an unrealistically low unit cost, the total costs of implementation would very rapidly become prohibitively large if the guidance recommendations were further lowered below the proposed values. This conclusion is based on estimates of areas which exceed certain soil contamination levels relative to the soil "screening level" for the proposed guidance (see Table 2.1). Actual costs of remedial actions are likely to exceed such a minimum value and will be substantially greater in most instances. Societal and environmental costs, while ordinarily not quantifiable in monetary terms, would further add to the total costs.

5. Department of Energy

For a given area, cleanup costs are apt to be largely fixed costs, which will not "necessarily increase as the difference between the existing contamination levels and those sought becomes greater." (p-17, lines 21-23)

Staff Response - The costs of remedial actions are necessarily speculative and will need to be determined on a site-specific basis. The stated minimum cost probably consists primarily of fixed costs, which become a progressively smaller fraction of the total cost as the scope and magnitude of remedial actions increases.

6. Department of Energy

How can it be "concluded that the costs...would be reasonable and achievable," when it is acknowledged in the previous sentence that "large uncertainties (are) involved?" Actually, the estimated costs are too low by a factor of 3 as compared to DOE estimates for the same treatment, and by at least an order of magnitude for any treatment consistent with the Guidance. Furthermore, the costs considered were only monetary costs. No consideration is given to environmental costs or the potential risks involved in cleanup and disposal. Also, the consideration of costs has been limited to sites of existing contamination, although the Guidance is also applicable to future contamination. Consideration should be given to the probable costs associated with possible future accidents. (p-18)

Staff Response - The conclusion that the costs of implementing the guidance for existing sites would be "reasonable and achievable" is based on an evaluation of the data on environmental contamination levels for these sites, which indicate that the sizes of areas which may require remedial actions at the proposed guidance levels are all relatively small. Therefore, regardless of the cost of remedial actions per unit area, the total costs are expected to be consistent with the objectives of the guidance.

Consideration of environmental costs and of potential risks is an integral part of the decision making process, and must be addressed in implementation of the guidance recommendations. Alternative actions, such as restricted occupancy, or use of lands, are available where soil disturbance or removal are either impracticable or detrimental on a long-term basis. The staff believes that the flexibility of the means for implementation offered by the Federal Radiation Guidance procedures, and the common sense of local and Federal officials, would make it possible to minimize the social and environmental costs effectively.

A more detailed discussion of costs as applied to remedial actions at both existing and future sites of contamination is given in Section 4.

7. Department of Energy

These numerical estimates of cleanup costs, by employing an unrealistic figure of $500/acre, and by ignoring environmental costs, lead the reader to the erroneous conclusion that great benefits can be obtained in the vicinity of Rocky Flats by the expenditure of only $100K or $500K. Even with more realistic cost estimates, this table seems inappropriate for the Summary Report because of the extensive further discussion required for its proper consideration.

"Less than" signs are not used consistently. If areas are "less than," corresponding costs should also be "less than." Actually, a "less than" value in a table such as this has little meaning since the reader has no idea of "how much less than."

It does not appear reasonable that a decrease in reference level by a factor of 3 would increase the area involved from zero to 80 mi^2 at the Nevada Test Site or from zero to 20 mi^2 at Trinity Site. This implies a degree of uniformity in contamination level that is difficult to believe. (p-19, Table 2.1)

Staff Response - The comment implies that EPA considers a reduction by a factor of three or ten below the Guidance recommendation as conferring a "great benefit." This is not correct, and the costs of such further lowering of the recommended dose limits would have to be balanced against the very small additional gain in public health protection. Even if it were assumed that the cost of remedial actions was as low as $500/acre, a further reduction is not warranted for the Rocky Flats Plant and the cost of averting one additional fatality would be at least several million dollars.

Areas of contamination represent best estimates. Data were derived from published contour maps prepared by the Department of Energy or its predecessors. Uniformity of contamination within contour intervals must be assumed in the absence of more definitive information.

8. Department of Energy

To the extent that costs of implementing the Guidance were considered in arriving at an acceptable level of risk, this level has most certainly been biased in the direction of an unjustifiable smaller risk. This is because the estimate of cost employed, $500 per acre, is an unreasonable monetary estimate low by a factor of 3 as compared to DOE estimates for the same treatment, and by at least an order of magnitude for any treatment consistent with the Guidance), and because it includes no consideration of non-monetary societal and environmental costs.

Staff Response - The costs of $500 per acre was assumed to be a minimum cost. It was intended to be used to demonstrate that, even if costs of remedial action were this low, the costs of proposing a dose limit that established a soil limit below 0.2 uCi/m^2 would be prohibitive. The $500 per acre cost was not used to establish an acceptable level of risk.

9. Department of Energy

One of the "two primary criteria used in determining the guidance recommendations..." was "...that implementation of the guidance be feasible in terms of overall economic impacts." (Summary Report, p.14). It is further noted on p.30 that "Monetary costs, environmental costs, and other non-monetary costs should all be considered in the evaluation of each alternative combination of possible remedial actions". From these statements one might anticipate that a considerable portion of the justification and explanation of the Guidance would consist of detailed analyses of the costs of required remedial actions. Such, however, is not the case. Two pages of generalities are devoted to "Costs of Remedial Actions" in Annex 5, and a single page plus table are devoted to the same subject in Annex VI. No references are given to any methods or sources employed in arriving at costs, and the only number actually used in the estimation of remedial costs is $500 per acre. Yet, assurance is given, on p.18 of the Summary Report, that "It can be concluded that the costs of implementing the guidance at the reference level would be reasonable and achievable". No justification is provided for this critical conclusion.

The $500 per acre figure employed for estimating "costs of remedial actions at various sites of existing plutonium contamination" appears to include $250 for radiological surveillance, $200 for dust stabilization and $20 for revegetation, rounded to $500/acre. These are unreasonable estimates for even the most minimal required action. They ignore the recommendations of Annex V on implementation, since estimates of contamination are based on existing data, obtained in a manner very different from that recommended by EPA, with few, if any, particle size analyses, and certainly no demonstration that the statistical probability of being in error is no more than 5-10%. These estimates, as applied to sites of existing plutonium contamination, are grossly misleading in terms of costs already incurred at these sites.

Of greater concern than these sites of existing plutonium contamination, are the costs that might be associated with future incidents of contamination. The possibility of such incidents should have been recognized and the costs estimated, including not only the monetary costs of actual cleanup and restoration, but the possibly greater costs of population evacuation or monitoring, of environmental impact assessment, of decontaminating homes, roads, or commercial areas, of income loss from cessation of agricultural or commercial activities, of demonstrating eventual compliance with the Guidance--and also including the environmental and non-monetary societal costs incurred, not neglecting the health risks of the cleanup operation. Any such total and realistic consideration of costs might well have led to a different conclusion concerning their "reasonableness and achievability"; which might, in turn, have influenced the choice of Guidance recommendations.

Staff Response - The $500 per acre was not determined from estimated costs figures. It was intended to demonstrate that even if costs of remedial action were that low, the costs of proposing a dose limit that established a soil limit below 0.2 uCi/m^2 would be prohibitive.

An estimated cost of remedial action of $500 per acre is undoubtedly low. However, it is a misconception to consider the cost of acquiring data on the concentration of transuranium elements in the soil to be a cost of remedial action. These costs would be incurred in any case, no matter the guide level established and would, presumably, be incurred even if there were no guide. The costs of acquiring data to determine if remedial action is required is better considered to be a cost of the incident of contamination than a cost of clean-up and restoration.

An important consideration in estimating the costs of future incidents of contamination is the probability of their occurance. This has been ignored by DOE. Actually, a set of probabilities is needed for covering a number of situations, so that the expected value (expected costs) of failure incidents can be determined. The set of probabilities should include not only the probability of the occurance of incidences of contamination, but also probabilistic expressions of the sizes of the expected incidences and the types of lands impacted (e.g., agricultural lands, forests, urban or industrialized areas.) DOE's discussion seems to assume that the probability of a future incident is one for the cases where costs are analyzed and zero for the cases where costs are not analyzed.

10. Department of Defense

The summary report states that "...generic guidance applicable to all sites cannot be provided by formal cost-benefit procedures". It also states that "The primary criteria used in determing the guidance...(is) that implementation of the guidance be feasible in terms of overall economic impact". The substance of the guidance is generic, regardless of what clean-up level is eventually determined because the guidance is stated in terms of a limiting dose which is the same for any site. This example is used to illustrate the inconsistency and ambiguity within the document as well as to question what was the basis for providing the generic guidance when one hand is saying economics prevented it and the other hand is saying economics was the primary criteria.

Staff Response - The objective of the recommendations is to establish a generic guide which is adequately protective of the public health. Formal benefit-cost procedures were not used in the derivation of the guidance recommendations because they do not lead to a generic guide; they would require that an independently determined level be established for each site.

Economic analyses were limited to a determination that costs of implementation for both existing and possible future sites are reasonable.

11. Nuclear Regulatory Commission

It appears that the costs of taking remedial action for facilities licensed by this Agency would substantially exceed the lower limit value of $500 per acre assumed for the proposed guidance. For example, disposal of surface soils by burial in commercial low-level waste burial sites would probably equal or exceed the costs of the general per cubic foot charge for burial. Using a value of $3 per cubic foot (NUREG-0217), would result in an estimated cost of $5000 per acre for burial charges alone. Using a value of $3 per cubic foot (NUREG-0217), would result in an estimated cost of $5000 per acre for burial charges alone.

Staff Response - We agree. While costs of remedial action may vary greatly, depending on level of contamination, location, land use and ecological factors, etc., the costs of remedial actions can generally be expected to be greater than $500 per acre. This is especially true in cases where long-term storage or burial is required. The assumed least cost value was used solely for purposes of setting a lower limit on the numerical limits, and does not represent an analysis of costs for cleanup and restoration at existing or possible future sites of environmental transuranium element contamination.

2.4 Implementation

1. Colorado Department of Health

The guidance document contains air concentrations and surface soil levels which are related to the numerical dose rate guidance. These air and soil values should be inserted in the text of the actual guidance with qualifying statements as to their appropriate use in the implementation of the guidance.

Staff Response - The guidance is stated in terms of dose rate limits to specific body organs. Derived air or soil "screening levels" are intended to assist in implementing the guidance in a cost-effective manner, and do not constitute the guidance. It would therefore be inappropriate and misleading to include these in the text of the guidance.

2. Department of Energy

Derived Limits for Air and Soil: The restrictive nature of the basic radiation dose limits is, of course, reflected in the derived limits for air and soil. Their derivation also introduces additional conservatism, which can be only partly justified in terms of their intended use as screening levels below which no action need be taken. The derived soil limit is featured in the Summary Report as a "screening level" and its utility in facilitating economical implementation of the Guidance is appropriately emphasized (p. 29). The derived air limit, however, is not found until Annex V (p. 6), and its use is recommended only as a last resort when other approaches are "difficult or impossible." It is not clear why the derived air limit cannot provide a screening level that is more useful than the derived soil limit, since the air limit is more directly related to inhalation hazard than is the soil limit. While it can be argued that an air screening level would ignore the ingestion route, the same argument applies to the soil screening level as it is presently derived.

Air Screening Level: It is recommended that an air screening level be identified as such, and given greater prominence in the Guidance. The level of 1 fCi/m^3 defined in Annex V, based on an unrealistic value of 2.6 fCi/m^3, employed in the derivation of the soil screening level (Annex 11, p. 33) seems more appropriate. In order to account for uncertainties introduced by not considering the ingestion route, and non-ambient inhalation routes, it is suggested that an "unqualified air screening factor" might be established based on a detailed analysis of the probability of significant contribution from other-than-routine inhalation exposure. Any number derived for an air screening level should, of course, be increased proportionate to any increase in the basic radiation dose limits.

Soil Screening Level: The relationship between the quantity of a radionuclide inhaled, and the quantity of that radionuclide in the soil is a complex one, which can be predicted only with great uncertainty. Because of this uncertainty, parameters chosen to develop such a relationship tend to produce a conservatively biased result. The mass loading approach employed in this Guidance has many faults which are pointed out in the Page-by-Page Commentary, together with suggestions for improvement. However, it is not clear that a totally different approach would yield a better result.

In these circumstances, a decision as to how conservative is conservative enough becomes rather arbitrary. However, the following list of conservatisms presently included would strongly suggest that the derivation of the soil screening level is more conservative than it need be:

(a) The assumed mass loading of 100 ug/m^3 is 2 to 10 times higher than shown by the data of Fig. A 2-2.

(b) The assumed percentage of the airborne particles in the respirable size range, 100%, is 3 to 4 times greater than shown by the data of Fig. A 2-3. Such an assumption is especially inappropriate when used in conjunction with a mass loading of 100 ug/m^3.

(c) The allowed air concentration of 2.6 fCi/m^3, based on AMAD of 1.0, is a factor of 2 smaller than would be allowed if the AMAD of the respirable fraction were more realistically assumed to be in the 2-5 um range.

(d) The lack of any correction for area size introduces a very large factor of conservatism, unless extremely large areas are involved. As pointed out in Annex II (p. 29), this may be a factor of 100 or more for areas with dimensions of the order of 50 meters. Such small areas of contamination are likely to be typical of most future contamination incidents.

(e) The assumed dry density of soil, 1.5 g/cm^3, is larger than normally observed for surface soils.

(f) The "Enrichment Factor" correction of 1.5, while small, is unjustified on any realistic theoretical or experimental basis. Its presence, while unimportant numerically, reflects unfavorably on the scientific credibility of the entire approach.

A shortcoming of the soil screening limit, as it is defined in the proposed Guidance, is the fact that it takes no account of the ingestion route. This route is, in some parts of the supporting material, implied to be insignificant, but in other parts cautioned to be possibly important. It may, under some circumstances, be as important as the inhalation route. The conservatism built into the present soil screening level is probably sufficient to accommodate such an ingestion component, but it would be more convincing to estimate the ingestion component independently and add it to an appropriately reduced inhalation component.

Staff Response - The agency staff does not recommend use of the soil screening level when inhalation is the principal pathway. Correlation of soil concentrations with inhalation doses requires calculational models which necessarily introduce some uncertainties. The potential inhalation hazard can be more directly related to the ambient air concentration.

Where ingestion is a possible pathway, the soil screening level has greater applicability. Although not derived on the basis of ingestion, the staff has found use of the soil screening level to be sufficiently concervative to limit exposures to less than the Guidance dose limits when plutonium is the major constituent of the transuranium element contamination. The derivation of the soil screening level was not based upon the ingestion pathway, since that is extremely site dependent - even more so than the inhalation pathway. Ingestion is not the principal contributor to the total risk at sites of existing contamination. For future accidents, the relative importance of the ingestion pathway is not possible to predict.

The staff does not agree with DOE that the soil screening level is more conservative than it need be for the following reasons:

a) A value of 100 ug/m^3 was chosen in order to cover the possibility that localized resuspension could also contribute to the inhalation dose. These local disturbances would not be reflected in the average mass loading for the general area. The value of 100 ug/m^3 is consistent with values used by others who also attempted to factor local resuspension into their calculations (see Annex II).

b) The percentage of airborne particles assumed respirable is not 100%. The assumption was that the particle sizes of suspended dust are distributed lognormally with an AMAD of 1.0 um.

c) A factor of 2 is not significant.

d) The size of the area contaminated by future accidents can not be predicted.

e) This would be a small correction.

f) Justification for the use of the enrichment factor is contained in Section 3.2, response to comment 30

3. National Council on Radiation Protection and Measurements

The approach taken is to provide dose limits for lung and bone. These limits are then to be applied by the agency responsible by a combination of measurements and models involving intake and retention since the dose to these organs cannot be measured directly. Unfortunately, these models and coefficients are not well developed and methods of measurement for inhalation of other than ambient air are not really available. This will result in adding considerable conservatism to the analysis and in continuing the controversy over the safety of a given area.

We would recommend that the EPA reconsider this approach in favor of setting soil levels that incorporate all known pathways of exposure and considering the necessary conservatism in these models along with any conservatism incorporated in the risk estimates and dose calculations. While this may provide a limit for some areas lower than is needed, it will allow consideration of all factors of conservatism and will provide an unequivocal number that can be accepted by all. We would also suggest that analyses of different areas be made taking into account, even crudely, all possible pathways to see if the area difference is as great as assumed.

Staff Response - The guidance is stated in the most direct units possible and is intended to provide for the deviations appropriate to specific sites. Use of a single "soil sceening level" would remove the possible options available without any compensating benefit. The inclusion of all appropriate factors of conservatism in a single numerical value would necessarily require that the most restrictive level be applied to all sites, with the consequence of possibly greatly increased costs of implementation and unnecessary damage to the environment.

4. National Council on Radiation Protection and Measurements

One of the concerns is the potential impact of future accidents that may release transuranics into the environment. The current guidance is not clear as to what should be done. In discussing the accident, it is stated that the material should be cleaned up"...as soon as possible..." However, elsewhere in the document we find requirements for detailed assessments are needed for the accident situation. We also note that no studies of potential accidents and cost of cleanup at this level as opposed to levels somewhat higher or somewhat lower were done to determine whether the reduction in risk is worthwhile. While such costs should be included in the cost of the operation, there is no reason to believe that this justifies unnecessary costs if not warranted by the risk reduction.

We recommend that the actions following a future possible accident be better defined and that a study be made to show that these limits are appropriate.

Staff Response - It is not possible to predict with any degree of confidence either the probability or consequence of future incidents which could release transuranium elements to the environment. The agency staff believes that the proposed criteria for protection of the public health are as appropriate for the case of future accidents as for existing contamination, and that no valid reason exists for establishing different dose or risk levels. Therefore, the recommendations of the guidance are intended to be viewed as minimum performance objectives, and lower values are to be attained when these can be achieved with reasonable expenditure of resources. Because the number of possible accident scenarios is virtually infinite, no useful purpose would appear to be served by evaluating the costs of risk reduction. The range of remedial actions required will depend on the magnitude of the accident and on the potential impact on individuals and populations. In most cases, a rapid response can be expected to minimize the consequences and reduce the overall costs. The interaction of all these variables would determine the appropriate response in each case.

In the opinion of the agency staff, actions following a possible future accident are generally defined by emergency response criteria and do not properly fall within the scope of this guidance. Planning for such emergency response is the responsibility of the agency under whose auspices the pertinent activity is carried out. If the anticipated consequences of any ongoing or projected activity are likely to exceed the guidance recommendations, an EIS may be required.

5. Department of Defense

There is confusion possible in terms of the radionuclides to which the guidance applies because of the wording. It appears the guidance covers all transuranium elements, yet it is stated in terms of alpha radiation doses. Some transuranium elements are not alpha emitters--how are these to be addressed?

Staff Response - The guidance is intended to apply to all transuranium elements. Beta emitters (such as plutonium-241) contribute little effective dose and need not be considered. Daughter products, which generally are alpha emitters, are included in the calculations.

6. Commonwealth Edison Company

Commonwealth Edison Company endorses the concept of "screening levels" for environmental contamination below which costly environmental surveys need not be undertaken to demonstrate compliance with the proposed dose rates. However, we believe that the derived value for airborne contamination suggested by the EPA is too low to be practical, and consequently will not accomplish the purpose for which it is intended. Specifically, we know of no way to measure accurately EPA's derived limit of 1 fCi/m^3. Further, it will not be possible to separate out the contamination resulting from an unplanned release of transuranics from ambient background contamination unless environmental surveys are conducted on a routine basis.

Staff Response - The detection of contaminants in air is a function of the concentration, sampler flow-rate, sampling duration, chemical yield of the analytical procedure, and the sensitivity of the analytical technique (see Bernhardt, Evaluation of Sample Collection and Analysis Techniques for Environmental Plutonium, in "Selected Topics: Transuranium Elements in the General Environment", EPA Technical Note ORP/CSD-78-1 (1978)).

The minimum sensitivity for plutonium-239/240 for most laboratories is generally around 10 to 20 fCi on the final sample submitted for nuclear counting. Assuming a fairly low yield of 50 percent this gives a minimum detectable sample activity of 20 to 40 fCi. For this example, this level is raised to 100 fCi per sample, to insure a reasonable analysis. Using the screening guide of 1 fCi/m^3 and a median sampler flow-rate of about 0.28 m^3/minute (10 ft^3/min), 100 fCi is collected in 360 minutes, or about six hours. For a long-term average, such as is specified by the EPA Guidance, sampling times of several days to a week are used. Sampling for about 3 days, using the above parameters, will result in about 1000 fCi (1 pCi) of activity on the filter (based on 1 fCi/m^3), which is well within the ideal range for low-level plutonium 239/240 analysis. An air concentration level for plutonium of 1 fCi/m^3 is greater than current levels of plutonium is ground level air due to fallout and, therefore, can be detected in the presence of fallout plutonium.

7. Jefferson County Department of Health

The offsite contaminated area around the Rocky Flats plant is under my jurisdiction as public health officer for Jefferson County, and I emphatically disagree with the statement in the guidance that "all offsite areas probably would be in compliance with the guidance recommendations". My own survey has shown levels of plutonium in surface respirable dust to be as high as 3,390 times fallout levels. Although the guidance states "The area is sparsely inhabited, and there are few people living in the particular area of concern", please be advised that the State Health Department approved this land (with 3,390 times fallout levels of plutonium) for residental development, and this move was blocked only with considerable difficulty. I estimate that in the area of concern originally established by the State Health Department, that as many as 100,000 persons may be settled if the efforts of developers are not restrained. Much of this area is now under development.

Table 2.1 on page nineteen compares the cost of remedial actions with existing plutonium contamination as indicated by isopleth maps. The areas noted to require remedial action at Rocky Flats are too small, in view of a recent survey utilizing respirable dust samples. There is significant contamination outside the isopleths referred to in this table.

Staff Response - The Agency staff does not believe that guidance recommendations should be evaluated in terms of multiples of fallout levels, but rather in terms of risk to the health of people. The staff also disagrees with the analytical procedures proposed by Dr. Johnson for surveying plutonium levels in the environment. The areas of disagreement are discussed in Section 7 of this document. The concentration of plutonium in offsite soil is highest near the site boundary and decreases with distance from the site. Therefore there is a potential for only a limited number of persons to be exposed to levels approaching guidance recommendations when the areas surrounding Rocky Flats are developed. The vast majority would potentially be exposed to much lower levels. The agency staff believes public health protection will be achieved under these conditions.

8. Ilene Younghein

Annex 1 p. 12 "The milk surveillance network around NTS does not analyze samples for plutonium." Why not? p.17 "of the approximately 8 curies onsite, more than half is believed to be stabilized by coverage with an asphalt pad and remedial measures are being taken to control the remainder to the extent practicable." Is asphalt considered to be a permanent solution to plutonium contamination? You did not define your remedial measures nor what is meant by extent practicable. What is really being said-that the measures taken are temporary-that to really remove the contamination would be extremely expensive and probably impossible.

Staff Response - (a) Plutonium does not accumulate in milk and cannot be detected (b) The Agency has not provided a judgment on the adequacy of remedial actions. The statement is a report on an existing situation.

9. N.Y. Federation for Safe Energy

The guidance speaks of clean up. How does one clean up water, and where does one take soil that needs scraping?

Staff Response - Transuranium elements are generally very insoluble in water and are associated primarily with sediments. Restrictions on use of drinking water supplies may need to be imposed if dose rates to individuals at a specific location approach the guidance recommendations.

Contaminated soils may be stored in designated repositories. A number of commercial facilities have been licenced by the States and the Federal government operates several high-level waste storage repositories.

10. Colorado Environmental Health Association

If the proposed guidance of 0.2 uCi/m^2 is affirmed by EPA and the scientific community, we recommend that all land areas with soil contamination exceeding the guideline be mitigated as described under "Remedial Actions and Economic Evaluation". Applying the 0.2 uCi/m^2 guideline to the attached figure of soil contamination would require that any area exceeding 30 dpm/g would require mitigation. Approximately 1 square mile outside the Rocky Flats boundary and about 1.5 square miles inside the boundary exceed the guideline.

Staff Response - The guidance recommendations are in terms of dose rate limits to individuals in a critical segment of the population, and not in terms of a soil contamination level. The scope of remedial actions which may be required to achieve compliance must be determined on a site-specific basis. The guidance is applicable only to those areas outside the limits of Federal facilities.

11. Colorado Environmental Health Association

Although the guideline fails to recommend a specific sampling technique, it appears that the respirable dust technique offers the most practical method of estimating exposures to human populations since dust-borne plutonium may be inhaled and is thought to cause lung carcinomas and leukemia.

Staff Response - We do not agree. Soil sampling and analysis methods represent a secondary means of assessing health impacts and of implementing the guidance. The superiority of the "respirable dust technique" has not been demonstrated (see Section 7).

12. Colorado Environmental Health Association

We feel that the discussion of soil contamination in the environmental impact statement has not thoroughly addressed the controversy pertaining to the amount of radioactivity in the soil. If the scientific community finds the EPA proposed Guidelines for Transuranium Elements in the Environment to be appropriate, then the standard should be applied to Rocky Flats and discussed in the Final EIS.

Staff Response - The guidance is not intended as an implementation manual and therefore does not discuss the merits of different soil sampling and analysis methods. Application to specific situations is the responsibility of Federal agencies having site juridiction. Preparation of an Environmental Impact Statement is required only for major Federal actions.

13. Department of Defense

This sentence is a non sequitur. It does not follow that just because all sources of transuranium elements are under direct control of the Federal Government that Federal guides are an adequate means to limit any problems of environmental contamination by the transuranium elements.

Staff Response - The Agency believes that Federal Radiation Guidance is both an adequate and equitable means of providing protection of the public health by establishing uniform dose rate limits for exposures due to environmental contamination by transuranium elements, while maintaining the flexibility of implementation not generally afforded by standards.

14. Department of Defense

This is typical example of use of non-specific, non-meaningful words and phrases. The term "as soon as possible" has little stature in a regulatory or compliance sense. A definite time should be specified. (p-18)

Staff Response - The Guidance contains recommendations which are intended to have a certain degree of flexibility. The indeterminate nature of the type, magnitude, and location of future incidents of contamination makes it both inappropriate and impossible to give specific directions for remedial actions. The objective of remedial actions must be to minimize both the immediate and long-range risk to exposed persons. It is the responsibility of the agencies charged with implementation of the Guidance to develop an adequate and timely response in each instance.

15. Department of Energy

Some recognition should be given to the fact that "as soon as possible after occurrence" could be a long time because of the complexities of establishing the extent and location of contamination and the cost benefit analysis required before remedial measures are taken--not to mention the possible requirements for an environmental impact assessment. The idea that there might be a desirable compromise between immediate, thoughtless recourse to bulldozers, and a 5-year study of environmental impact, should somewhere find expression in this Guidance. (p-18, line 25)

Staff Response - It was deemed appropriate to allow flexibility in implementation procedures and schedules. It is expected that common sense judgments, designed to minimize the health risks of individuals and the population, will be made by designated officials.

However, the agency staff wishes to emphasize that analyses indicates that, when a contaminating event occurs, most of the radiation dose associated with the event is committed within a short time (within a few months) unless protective measures are taken. This is because the resuspension factor for newly deposited material is much higher before weathering and movement into soil surfaces occurs.

Should a potential contamination event occur, the responsible Federal agency should take immediate remedial measures to prevent the airborne movement of the transuranium element. These measures are likely to be temporary measures that simply hold the transuranium elements in place. Following such temporary measures, remedial measures appropriate to a long term solution should be implemented.

16. Department of Defense

For health physics and protection reasons, why not also state the millrad numbers in millirem equivalents. From a regulatory standpoint, millirad is preferred for regardless of what quality factor is chosen for alpha, the guidance is the same. But for practical purposes, the protection industry works in millirem. (p-21, lines 3-4)

Staff Response - The conversion, if necessary or desirable, can easily be made in implementation manuals.

17. Department of Defense

A conclusion that is not supportable appears in the following paragraph where it is stated that "the control measures are expected to result in levels well below those specified in paragraph one" i.e., 1 and 3 millirad. Why would this be expected? If remedial action is done to the degree required literally, then one would reasonably expect that the levels would be not more than 1 and 3 millirad, but certainly not "well below." This typifies many examples of the luxuries the authors have taken throughout the document in making subjective statements, loose associations and rambling discussions. (p-21, para. 1)

Staff Response - In general, it may be expected that, if remedial actions are applied to all areas which exceed the soil "screening level," this will result in an average environmental contamination level lower than the "screening level" and result in dose rates to individuals well below the guidance recommendations. It is not reasonable to expect that responsible implementation of the Guidance recommendations, where remedial actions are actually required, would stop at the minimum requirement. Literal interpretation of the "screening level" as the absolute lower limit is obviously not in the spirit of achieving maximum radiation protection of the general population.

18. Department of Defense

Remedial action is stated as "may be required at any site that fails to meet these criteria." Presumably, since this is a guidance that limits the dose to man because of contamination of transuranium, remedial action would be required at any site that fails to meet the criteria. (p-30, Sec. 3.4)

Staff Response - Adherence to the guidance recommendations on the part of the responsible Federal agency is not mandatory, but adequate justification must be given for deviation.

19. Department of Defense

The DOE does not believe that "all sources of transuranium elements are under direct control of the Federal Government" (e.g., foreign space satellite components). Further it does not follow that "Federal Guides...are...an adequate means to limit any problems of environmental contamination," especially since all potential sources of transuranic elements are not under Federal control. (p-12, lines 9-12).

Staff Response - The amounts of transuranium elements not under direct control of the Federal Government are considered minimal and unlikely to cause significant problems. Foreign intrusions, such as the reentry of a Soviet space satellite, would need to be considered on an ad hoc basis. Federal intervention is considered likely in the event of any substantial contaminating event involving transuranium elements, irregardless of ownership.

20. Department of Energy

Again, unless "guidance recommendations" is understood to be strictly limited to the radiation dose limits, it is erroneous to say that they represent a "maximum value." The wording encourages misunderstanding. since the "screening level" might well be considered a "guidance recommendation" but should certainly not be considered a "maximum value." (p-20, lines 15-16)

Staff Response - The comment indicates a misinterpretation of the statement referred to. The recommendations are to be considered as upper limit values and the principle of "as low as reasonably achievable" is to be applied to the extent practicable.

21. Department of Energy

This sentence should be referenced to the place in this Guidance where "representative measurements" and "reasonable procedures and assumptions" are defined. (p-24, lines 2-5)

Staff Response - The discussion of details pertaining to implementation procedures is not appropriate in this Guidance.

22. Department of Energy

Although a soil "screening level" is a potentially useful concept, ambiguities concerning how the screening level is to be employed, either technically or administratively, make it of questionable practical value. Annex V offers little help in this regard. (p-29, lines 11-15)

Staff Response - The soil "screening level" is an optional method available to the implementing agency, which we believe to be practical and useful. Development of detailed technical and administrative procedures are the responsibility of the implementing agency.

23. Department of Energy

"Remedial action may be required." It is nowhere quite clear whether remedial action is ever required, or whether radiation dose in excess of EPA Guidance may be justified in some manner. (p-30, lines 7-8)

Staff Response - The Guidance recommendations should not be exceeded unless deviations are justified.

24. Department of Energy

The alternative of "restricted access, or use" is mentioned, but receives no further consideration. There are degrees of usage that might well be discussed. (p-30, line 12)

Staff Response - The Guidance document is not intended to be an implementation manual.

25. Jefferson County Department of Health

I am concerned with the criteria on page 60957 in the first paragraph, Rationale for Guidance. One of two primary critera used in developing this guidance, "That any actions required by implementation of the guidance be practical in terms of overall economic requirements". In view of the nature of the guidance proposed, I feel that economic concerns have really been given foremost consideration, perhaps with intent to minimize any economic impact on federal agencies or private corporations which have contaminated offsite lands. It appears to me that the concern for the public health has been given lower priority here.

Staff Response - The criteria for establishing the guide level was that the risk to exposed individuals be acceptable. This level was determined with no consideration for the costs of remedial action. EPA then determined that the costs of performing the required remedial actions were practical.

2.5. Biological and Environmental Models

1. Ilene Younghein

"A more detailed treatment of the dose to children is not likely to result in appreciable difference in the risk since most of a person's body burden is accumulated during adult life, not childhood." This statement is very questionable. Children's cells grow and divide faster so radiation damaged cells proliferate faster. Also children carry the damaged cells for longer periods of time. Children too would be more penalized by the life shortening process of radiation than an adult. It is also possible for plutonium to cross the placenta, from the mother's blood into the blood of the fetus, where it may kill a cell responsible for development of part of an organ, such as heart, brain, liver etc, causing deformities to occur in the developing fetus. This mechanism for production of fetal deformities is called teratogenesis and is different from the deformities caused by genetic mutation in the egg or sperm (similar to the drug thalidomide). The discussion on risks to children is incomplete and misleading (Section 3.2 p.5).

Staff Response - All of the points mentioned in the comment were considered in the assessment of risk. Refinements in the dose model for children are unlikely to change the numerical risk estimates to any appreciable extent.

2. Ilene Younghein

Contrary to your statement, it is possible to get a lifetime dose of Pu 241 (half-life 14.8 years) and Cm (half-life 17.9 years). These elements stay radioactive for about 148 and 179 years-longer than the life of most people, especially those exposed to plutonium.

Staff Response - For a relatively constant food intake quantity characteristic of most persons, the annual dose rate from ingestion of transuranium elements is expected to be roughly proportional to the environmental contamination level. For such relatively short half-life radionuclides, the initial dose rates are not expected to be maintained over the entire lifetime of an individual.

3. Ilene Younghein

"..for chronic iradiation due to Pu-239, 200 bone cancers will be produced per 10^6 rad to a 7 kg skeletal mass. In terms of the dose to mineral bone, mass 5 kg, utilized in this analysis, there results yield 140 bone cancers per rad to osseous tissue." This section is unclear at best, at worst incomprehensible.

Staff Response - The statement is a simple scaling of a result obtained from the technical literature to the slightly smaller bone mass used in the EPA analysis to provide consistency with ICRP models.

4. Commonwealth Edison

Although the proposed guidance seems to apply to all Federally licensed facilities with any transuranics in their systems, it would be technically unjustifiable to require nuclear power plants to conduct environmental surveys following every planned release of radioactivity to prove that the derived contamination guidance has not been exceeded.

Staff Response - Federal Radiation Guidance is applicable only to the Federal agencies and is advisory to the States. It is prudent, however, for Federally licenced facilities to evaluate the impact of unplanned releases that are sufficiently large to cause dose levels to populations of the same order of magnitude as the guidance recommendations.

5. National Council on Radiation Protection and Measurement

The screening level derivation in Annex II does not reflect the requirements of the remainder of the document. Only the ambient air concentration is used and even this is calculated by a mass loading technique with an enrichment factor that has not been justified by an experimental work. We find, for example, that ingestion for the reasonably serious home gardener could be of importance if the uptakes from the GI tact from Annex III are used. This is particularly true for the nuclides other than plutonium.

We recommend a detailed study of all pathways in derivation of the screening level with some emphasis on size of the area. In particular, the inclusion of the enrichment factor which apparently makes a difference on only a factor of 1.5 and has never been demonstated to be proper should be reconsidered.

Staff Response - The staff has analyzed the situation where the entire surface inventory of 0.2 uCi/m^2 consists of transuranium nuclides other than plutonium. These nuclides generally have higher plant uptake and GI tract transfer factors and, therefore, result in higher doses. However, the dose rates are not projected to exceed the guidance limits even for the serious home gardener.

A discussion of the applicability of the enrichment factor can be found in comment 30 of Section 3.2.

6. Jefferson County Health Department

It must be noted that although "soil contamination levels can be related to a corresponding air concentration by use of a resuspension factor", in the copy of the proposed guidelines it is admitted that such a resuspension factor may vary by a factor as large as one million, which makes the use of such factors highly questionable. The guidance states on page 60958 that a soil contamination level of 0.2 microcuries per square meter (with samples collected at the surface to a depth of 1 cm. and including particles less than 2 millimeters in size) would establish a reasonable "screening level". The use of whole soil samples to evaluate a hazard from respirable dust is inappropriate and will underestimate the hazard, as I have demonstrated in my work around the Rocky Flats plant in Jefferson County. In addition, the value proposed is too high to be acceptable to the general public, in my opinion, if the public understands the range of estimates of ill effects that could result in a total increase in all neoplasms of perhaps 1 to 2% over a period of 70 years. The incidence of all genetic disease could increase by 1% and ill health related to chromosome mutation by about 7% for all succeeding generations from the proposed guidance dosage level.

Staff Response - Annex II of the Proposed Guidance document discusses in detailed the difficulties involved in applying the resuspension factor concept to predicting the resuspension of surface soil. Because of the many limitations of the resuspension factor concept, the agency staff chose not to use it when deriving the soil screening level. Instead the staff used the average airborne mass loading when deriving the soil screening level, after some modification to account for the distubution of activity with soil particle size.

It has not been demonstrated that the soil sampling and analysis techinque proposed by Dr. Johnson correlates in any way with the airborne concentrations observed in Jefferson County. In fact, since this analytical technique drastically alters the distribution of activity with soil particle size from what it is in the environment, it is doubtful that any such correlation can be made. The staff has compiled a detailed critique of the sampling and analysis method proposed by Dr. Johnson. (See Section 8).

Additionally, the staff has identified several erroneous assumptions made by the commentor in converting levels of resuspended dust into dose from inhalation. These errors result in projected doses far exceeding those which would actually be received by persons living in the vicinity of land contaminated at the level of the 0.2 uCi/m^2. (See Section 8)

7. Jefferson County Health Department

In paragraph two on page seven, the report states "the uptake by plants is relatively small, and most animals, including humans, have a high discrimination factor against transfer of these elements into the body tissues". However, some plants, such as algae and seaweed, have the ability to concentrate plutonium, presumably in a form that can be assimilated by animals. Chelating agents present in soil over a period of time may make the plutonium oxide in soil available for uptake by both plant and animals to a greater extent.

Staff Response - The uptake of plutonium by plants has been the subject of numerous laboratory and environmental studies. These studies have demonstrated a low uptake by terrestrial food plants. The uptake factors are typically in the range of 10^{-4} to 10^{-6}. It is true that some marine plants show higher uptake factors, but their contribution to the American diet is very small.

The Guidance establishes a limit on doses from all pathways to which persons are exposed and, if a situation arises where the marine food pathway is significant, this would not invalidate the Guidance. Likewise increased solubilization which increases the uptake of plutonium by plants would not invalidate the Guidance.

Several mechanisms have been suggested which can increase the solubility of plutonium. Much of this research is in the preliminary stage and a quantitative discussion of the time required for such transformations is not currently possible. The preliminary data, however, have not demonstrated that rapid transformation of plutonium occurs under conditions generally encountered in the environment. Most likely, if such transformations do occur, they occur over long periods of time (decades).

8. Jefferson County Health Department

The table on page five (table 1.2) indicates a soil concentration of 0 to 1,000 picocuries/gram (pCi/g) of plutonium on site. However, these values have been previously reported to be as great as 13,600,000 pCi/g (INV-10 report)*. Therefore, to say that the onsite maximum is in excess of 1,000 pCi/g seems misleading. The same comment may be applied to the level given for plutonium in soil at the plant site boundary. As much as 80 pCi/g has been measured in samples of surface respirable dust off site.

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* "Levels of 2×10^5 dpm/g to over 3×10^7 dpm/g reported."

Staff Response - All uncontained on-site soil at the Rocky Flats Plant site contaminated above 2000 pCi/g (about 21,000 square feet) is currently being removed by DOE.

9. Jefferson County Health Department

In addition to resuspension of plutonium from surface dust, we must also consider the release of particulate plutonium from plutonium-processing plants. These particles are for the most part less than five microns (micrometers) in size and large numbers are released at times. Eight days after a fire at Rocky Flats in 1957, as many as 125 million of such five micron particles or their equivalent were released in a single day from one stack. A two micron particle of plutonium oxide, if inhaled, would produce a dosage of over two millirem to bone. A particle five microns in size could be inhaled and retained and produce a dose about 40 millirem to the lung, 1,700 millirem to the tracheobronchial lymph nodes, over 130 millirem to the bone, 50 millirem to the liver, eight millirem to the kidney, and two millirem to the gonads, where a pattern of microdeposition of plutonium would give a proportionately greater effect than the same order of size as bacteria, and may be blown by the wind for great distances. A single particle only two microns in size, if inhaled and retained, will produce a dosage exceeding the EPA 4 millirem annual dose.

Staff Response - These recommendations are to be used only for guidance on possible remedial actions for the instances of existing contamination or of possible future unplanned releases similar to the incident described.

The agency staff does not agree with these dose calculatins. As indicated earlier, the agency staff has identified several erroneous assumption made by the commentor in converting from levels of resuspensed dust to inhalation doses. These are described in Section 8 of this document.

10. Jefferson County Health Department

On page 28 (Implementation) the guidance states "in most cases the critical pathway for exposure to transuranium elements is through inhalation of airborne particulates derived from resuspension of soil particles and compliance with this dose guidance can be demonstrated by measurements of air and/or soil concentration". The problem with the use of soil samples (agricultural soil) is that much of this material is coarse and is not windblown, and when included in the samples used to evaluate windblown material, misleadingly low results are obtained. The best way to evaluate a hazard from airborne contaminated dust is by use of a respirable dust sample from the surface of the soil.

Staff Response - Regardless of the soil sampling technique, a relationship must be established between the measured soil contamination and the actual airborne activity. Dr. Johnson has not established such a relationship for his respirable dust sampling technique. Even if a satisfactory correlation could be established for the sampling method, the Dr. Johnson's techniques does not correspond with the lung deposition models developed to calculate inhalation doses. These models require a value for the total airborne activity and a description of the distribution of that activity as a function of particle size. Dr. Johnson's technique does not provide such data and therefore does not provide a method for evaluating the potential inhalation hazard.

11. Jefferson County Health Department

There are problems with the estimation of the air concentration of plutonium due to the efficiency of filters used in air monitoring devices, the velocity of air intake, the variation in concentration of resuspended plutonium by height above the ground surface, and other local factors. In addition, such measurements are given in averages per cubic meter whereas plutonium is particulate, i.e., the inhalation of one particle of respirable size (two microns) per year would exceed the 1976 EPA regulations. The effectiveness of such filters in retaining the orders of sizes of plutonium oxide smaller than 0.1 micron needs to be evaluated. I would agree with the guideline that "therefore soil measurements may be more advantageous in certain areas" except that these should always be performed.

Staff Response - There are problems with any method of measuring environmental contamination level, whether it be in air, soil, or water. Such measurements are difficult because of the generally low concentration levels, non-uniform distribution, and other similar factors. The collection efficiency of filters and of other sampling devices can generally be determined and appropriate correction made in the reported results.

The agency staff prefers the measurements of airborne radioactivity to soil measurements when evaluating an inhalation hazard, for the following reasons:

1. Air measurements provide a method for averaging over larger volumes than do soil measurements.

2. Air measurements show less point-to-point variation. Values of soil concentrations can vary dramatically over a distance of only a few meters. How this variation will be reflected in the overall inhalation risk is difficult to evaluate.

3. Air monitoring can be performed on a continuous basis and therefore provides a method for averaging over many changes in climatic factors.

4. Air measurements provide a method for evaluating the impact of a contaminated area which is some distance from the population at risk.

5. Measurements of the radioactivity in the air to which populations are exposed can be more directly correlated with the potential inhalation hazard. Soil measurements require a calculational model to relate the soil levels to the resuspended activity. Such models introduce uncertainties and, therefore, must be conservative in nature so that the actual inhalation hazard is not underestimated.

12. Jefferson County Health Department

The soil sampling suggested by the agency is agricultural soil, ie., particle sizes under two millimeters in size, collected to a depth of one centimeter. This type of sample is inappropriate for use in evaluating a hazard presented by contaminated respirable dust. The suggested "screening level" for soil contamination of 0.2 microcuries per square meter is equivalent to about 29 disintegrations per minute per gram, assuming a soil density of 1.5 gram per cubic centimter, and is a concentration much too high to be considered safe for residents of such areas. This level is about 15 times greater than that now recommended by the Colorado State Health Department (0.01 microcuries per square meter, or 2 dpm/g) except that the state interim standard is addressed only to plutonium, and does not include other transuranium elements. Samples of respirable dust compared to whole soil samples collected by the method used by the state have indicated as much as 285 times as much contamination with plutonium as indicated by whole soil samples. Plutonium in the surface respirable dust offsite is as much as 3,390 times the background value from fallout in Colorado. Therefore, I believe that the use of whole soil sampling, as advocated by these proposed guidelines, is inappropriate and will certainly underestimate the hazard.

Staff Response - The Guidance recommendations refer only to dose rates to organs of persons in the general population. Comparisons on any other basis are inappropriate.

A critique of the respirable dust sampling method proposed by Dr. Johnson is contained in Section 8 of this document.

2.6 Miscellaneous Comments

1. Department of Energy

Footnote is misleading. Long persistence is not a requirement for environment impact. Also, the ^{238}Pu daughter of ^{242}Cm is not shortlived. (p-2, Table 1.1)

Staff Response - We agree.

2. Department of Defense

"more or less uniformly" is an ambiguous and misleading description of the extensively studied distribution of fallout. (p-3, lines 8-10)

Staff Response - The wording is meant to convey the idea that, while local concentrations may vary from the mean by up to a factor of two, fallout represents a relatively constant fraction of the total background level in the United States.

3. Department of Defense

"More or less uniformly" is ambiguous and misleading with regard to fallout. Why not just state that fallout has been slowly deposited over the lands and oceans and the level now is x microcuries/meter^2? (p-3 lines 8-10)

Staff Response - Fallout has not been deposited entirely uniformly and varies by more than a factor of four from the lowest to the highest current soil concentration level. Designation of an "average" background level of "x" microcuries/meter^2 would be erroneous and misleading.

4. Department of Energy

"The principal modes of transport" are not as certainly established as this sentence would suggest. (p-4, lines 13-16)

Staff Response - The agency staff has considered information applicable to all modes of transport to man to the extent available in the literature, and believes this to be sufficient to support the Guidance recommendations.

5. **Department of Energy**

Title of table might more appropriately refer to transuranics rather than plutonium, since 20,000 Ci of U.S. fallout must include ^{241}Am. If only plutonium, the U.S. fallout inventory is 16,000 Ci. (p-5, Table 1.2)

Staff Response - We agree.

6. **Department of Energy**

Several inventories and concentrations noted as "greater than" have little meaning. How much greater than? The comparison between 45 Ci listed for the Trinity Site and 155 Ci listed for the Nevada Test Site suggests that " 155" must mean "very much greater than," since it seems that the single small test at the Trinity Site would produce insignificant fallout compared to the many tests at the Nevada Test Site. This may not be true but the reader may well draw such a conclusion. (p-5, Tabel 1.2)

Staff Response - The data were derived from various sources and indicate best estimates of the Department of Energy.

7. **Department of Energy**

Listed soil concentrations have no value without specification of sampling depth. The footnote seems to imply a 1 cm depth, but this is probably not applicable to all values. It would aid comprehension if all soil levels throughout the document were converted to an area basis rather than leaving it for the reader to make such a conversion, which he often cannot make because of lack of information on sampling depth and soil density. (p-5, Table 1.2)

Staff Response - Conversion of measurement results is only possible where all the data are available. Sampling depth, variation of concentration with depth, soil density, and other variables are often not explicitly stated and would make the results of conversions ambiguous. Additional details for specific sites are given in Annex I.

8. **Department of Energy**

There are numerous inconsistencies between Table 1.2 and Table A 1-5 of Annex I. These two tables should either be identical, or one should be abstracted from the other. (p-5, Table 1.2)

Staff Response - We agree.

9. Department of Energy

There is a major problem with Savannah River Plant data, which cannot be verified in references cited in Annex I. The total inventory should be 1-2 Ci. "N area" should be "H area." The correct numbers are: for H area, 0.41 pCi/g; for F area, 0.08 pCi/g; and for perimeter, 0.01 pCi/g.

These numbers are derived from data presented in McClearen, H. A., "Plutonium in Soil at the Savannah River Plant," DPSPU 74-30-14, AEC Environmental Protection Conference, Albuquerque, NM (1974). (p-5, Table 1.2)

Staff Response - We accept the Department of Energy correction.

10. Department of Defense

What is the significance of light lines vs heavy lines in the schematic? (p-6, Fig. 1)

Staff Response - Heavy lines are intended to represent the more significant pathways.

11. Department of Energy

Caption should explain significance of different kinds of lines. Arrowhead is omitted on line from water to sediments. (p-6, fig. 1)

Staff Response - We agree. (see DOD comment 10)

12. Department of Energy

^{241}Am is probably more important than ^{238}Pu. (p-7, line 23)

Staff Response - Am-241 is only more important in weapons grade materials.

13. Department of Defense

The inference concerning biology is loose. It is not established that the pulmonary region is not a probable site for plutonium induced cancers nor is it true that plutonium oxides may contribute only marginally to bone cancer. (p-9, para 1 and 2)

Staff Response - The information given here is specified as applicable only to the inhalation pathway. Details on the assumptions used in dose calculations are given in Annex III.

14. Department of Energy

The pulmonary region may well be the most probable site for plutonium-induced cancer in humans. (p-9, lines 4-6)

Staff Response - The statement in the document merely says that the Agency combined the two more conservative assumptions.

15. Department of Energy

Some forms of plutonium oxide, particularly $^{238}PuO_2$, may be rather quickly translocated to bone. In such cases the frequency of bone tumors may exceed that of lung tumors. (p-9, lines 11-14)

Staff Response - True. The more soluble forms of plutonium oxide do translocate quickly and increase the risk of bone and liver cancers. However, in that case, the risk of lung cancer is decreased because of the shorter residence time in that organ. (See Section 6)

16. Department of Energy

"dpm/g in the top 1/8 inch of soil" should be translated into units used elsewhere in the document. (p-11, line 17)

Staff Response - The units are stated as given in the applicable Colorado standard.

17. Department of Energy

Here and elsewhere in the Summary Report, it would be very helpful if more specific references were made to material in the Annexes that support the conclusions stated. The lack of supporting justification in this Section is acceptable only if one is explicitly directed where this justification can be found. (p-14, Sec. 2.4)

Staff Response - In the absence of more detailed and definite information, an answer cannot be provided for this comment.

18. Department of Energy

This sentence is grammatically confusing and difficult to follow. (p-14, lines 17-21)

Staff Response - We believe the intent to be clear.

19. Department of Energy

The first criterion, by use of the words "very small," almost seems to preempt the second criterion. What happens if implementation at a "very small" risk level is not feasible? The occurrence of such ambiguities here and elsewhere tends to reduce the effectiveness of the document. (p-14, lines 21-25)

Staff Response - The ambiguities referred to may be in the eye of the beholder. The agency staff believes that DOE estimates of costs are greatly excessive and that a very small risk level and achievable costs of implementation are compatible in most cases.

20. Department of Defense

To what does "change by factors of 10" refer? Is it costs, soil concentrations, calculational precision? This is unclear. (p-10, line 10)

Staff Response - "changes of factors of 10" is intended to apply to soil concentration.

21. Department of Energy

The intended meaning of "beyond the boundaries of the source from where it orignated" is not clear. Does this mean off-site? (p-18, line 2-3)

Staff Response - Yes.

22. Department of Energy

The term "numerical guide" is ambiguous. What exactly is meant? (p-18, line 23)

Staff Response - The term refers to the numerical guidance recommendations.

23. Department of Defense

In view of later comments on Annex VI, this table adds nothing for the summary. (p-19, Table 2.1)

Staff Response - The table is intended to give a comparison of impacts at alternative guidance recommendation levels and may be useful from that viewpoint.

24. Department of Energy

The term "numerical guide" is ambiguous. If, for example, it were interpreted to mean "screening level," the statement would be incorrect. (p-20, line 1)

Staff Response - See response to comment 22.

25. Department of Energy

The appearance of the official "Text of Proposed Guidance" at the end of the section that discusses it, is awkward. It would be easier to understand the discussion if the Guidance appeared at the beginning of this section and was followed by discussion which went somewhat farther in justifying the exact form of the Guidance. (p-20, line 19)

Staff Response - Section 2 of the Summary document discusses the rationale for the proposed Guidance. The text follows logically.

26. Department of Defense

This chapter supposedly has the purpose of summarizing the proposed guidance, yet the proposed guidance does not appear until page 20. As a matter of writing style and to improve clarity, why not introduce the chapter with a statement that EPA, under its appropriate authority, is proposing guidance for transuranium elements, etc., the text of the proposed guidance is etc., and then follow with the discussion. It is now presented awkwardly if not backwards. (p-20, Section 2.5)

Staff Response - See response to comment 29.

27. Department of Energy

It does not appear that the Guidance, as stated here, would permit exceeding the dose limits on the basis of risk-benefit considerations. This seems unfortunate. For example, the very low risk incurred by exceeding the specified limits by some small factor might well be acceptable if the alternatives to cleanup lead to an uhacceptable risk-benefit ratio. (p-21, lines 3-4)

Staff Response - Guidance recommendations retain flexibility of implementation. Deviations may be permitted when properly justified.

28. Department of Energy

"Guidance on possible remedial action" sounds very weak. What exactly does it mean? It should be explicitly defined in the text of the Guidance. (p-21, lines 11-12)

Staff Response - We agree. The text has been changed.

29. Department of Energy

Definition of "critical segment of the exposed population" is imprecise. Could it be a group of two individuals with very unusual habits? (p-21, lines 18-20)

Staff Response - The guidance limits apply to that group of persons in the general environment who, because of residency or other factors can on the average be expected to receive the highest lifetime radiation dose from a specified source of transuranium elements.

30. Department of Defense

Definition a. "Critical segment of the exposed population" is vague, Definition d. replace following with during. Definition g. "general environment" means all the environments outside the boundaries of Federally licensed or controlled facilities, does this mean that lands inside the boundaries of similarly controlled facilities are exempt from the guidance? Definition h. Why define "curie" when it has not been mentioned or employed previously. One might as well define x-ray, beta or any other term as far as relevance is concerned. (p-21)

Staff Response - a. "Critical segment of the exposed population" is defined above; b. we agree; c. yes. The guidance is applicable only to those persons residing outside the boundaries of Federally licenced or controlled facilities; d. see response to comment 32.

31. Department of Energy

"Equilibrium dose rate following chronic inhalation" is incorrect. It should be changed to read, "equilibrium dose rate during chronic inhalation." (p-22, lines 3-4)

Staff Response - We agree.

32. Department of Energy

Since "curie" is not employed anywhere in the Text of Proposed Guidance, why is it defined here? If mCi and fCi are to be defined, why not uCi, nCi and pCi? (p-22, lines 17-21)

Staff Response - The definition should be deleted.

33. Department of Energy

The "small fraction" translocated is not small. (p-25, line 6)

Staff Response - The solubility of most inhaled transuranium nuclides is small and therefore the fraction dissolved in the bloodstream is necessarily small.

34. Department of Energy

This sentence should be referenced to the place in this Guidance where bone and liver cancer risk is derived. (p-25, lines 18-22)

Staff Response - The section is a summary of the detailed evaluations in Annex 3.

35. Department of Energy

The term "cohort" should be defined. (p-25, footnote)

Staff Response - The definition of "cohort" as used in the Guidance is: a group of 100,000 individuals with age in common. In the analysis, the mortality experiences of all the members of the cohort are traced from birth to death.

36. Department of Energy

This sentence should be referenced to the place in this Guidance where genetic risk is derived. (p-26, lines 16-17)

Staff Response - Genetic risks is discussed in detail in Annex 3.

37. **Department of Energy**

The genetic risk to succeeding generations is confusingly and inaccurately stated. The numbers quoted are an equilibrium rate *assuming continuing exposure*, generation after generation. The term "as high as" is confusing, when followed by a range. (p-26, lines 19-22)

Staff Response - We agree, see Annex 3.

38. **Department of Defense**

Replace *and* with either *as* or *since*. (p-27, line 3)

Staff Response - The sentence reads as intended.

39. **Department of Energy**

The term "environmental radiation dose commitment" should be defined. (p-27)

Staff Response - The definition of "environmental radiation dose commitment" as used in the Guidance is: "the total dose accumulated by all individuals in a given population over a designated period of time."

40. **Department of Energy**

This sentence has a syntax problem. The conjunction "and" should be changed to "since," or, better, dropped to form two sentences. The content of this sentence is important and deserves greater emphasis than it is given. (p-27, lines 23-25)

Staff Response - The sentence reads as intended, and represents parallel conclusions.

41. **Department of Defense**

The use of "over a prolonged period of time" is another example of using non-specific quantifying phrases and has no meaning--is it a year, 10 years, lifetime or what? (p-28, line 5)

Staff Response - The phrase is purposely non-specific to avoid the impression that only a lifetime exposure is significant.

42. Department of Energy

A "prolonged period of time" should be more explicitly defined. (p-28, line 5)

Staff Response - See comment 41.

43. Department of Energy

"Bites and stings" should be attributed to venemous animals and insects. Electric current is not hazardous when confined to "home wiring and appliances." The fatalities should be attributed to electrocution or electric burn or shock. (p-28, lines 6-7)

Staff Response - The meaning would seem clear to the intelligent layman.

44. Department of Energy

It should be made clear that the purpose of these soil measurements is to locate the specific areas of contamination. (p-29, lines 2-3)

Staff Response - We agree.

45. Department of Energy

"Suggests" may be too weak a word; "recommending" might be more appropriate. (p-29, line 12)

Staff Response - We agree.

46. Department of Energy

Specification of particle size seems an unnecessary complication for a "screening level" already burdened with many conservative assumptions. (p-29, line 14)

Staff Response - The specification limits the inclusion of large particles, and follows the definition of "agronomic soils."

47. Department of Energy

This paragraph is an example of the imprecise wording that deprives the Guidance of practical utility. (p-28, lines 18-23)

Staff Response - We believe the wording to be precise and the intended meaning clear. The paragraph admonishes the implementing agencies to consider all pertinent pathways.

48. Department of Defense

Overall, the chapter does not read well, is constructed poorly from the standpoint of style and clarity, is imprecise and lacks definite statements.

Staff Response - de gustibus non disputandum est.

49. Ilene Younghein

If we continue with our present nuclear energy plans, by the year 2000 we will have accumulated roughly 1.6 million pounds of plutonium-including plutonium from breeders-according to estimates by Glenn Seaborg. Even with 99.99 percent storage reliability, the nuclear industry will release 160 pounds of plutonium each year. If 1.6 micrograms can cause cancer in a non-smoking adult - that is enough to provide minimum potential lung cancer doses for about 15 times earth's present population.

Staff Response - Control and accountability of plutonium is orders of magnitude better than the number stated, and is expected to improve. The assumption that the entire release is transferred through the environment to become the body burden for humans is patently absurd. Transfer and uptake mechanisms are discussed in the Technical Summary.

50. Ilene Younghein

Section 1.2 is vague. You said more recent weapons tests have not added significant amounts to this level. What do you mean by significant? Also what do you mean by significantly higher amounts in refering to Bikini and Enewetak. Is that a way of avoiding how much radiation is really there. Other mushy language is about the underground detonation where you said that it is contained below the earth's surface and is not expected to be readily avilable for uptake by humans. Areas of high concentrations may be well documented, but long term health effects have not. The fact that most of the contamination is on Federally owned property says something about the carelessness to which public trust, is carried out. Everybody's land is nobody's land.

Staff Response - a) "Significant" changes of environmental contamination levels are usually considered to involve increases of at least twice the standard deviation of observed values.

b) Data for Enewetak atoll are given in Annex I.

c) The guidance is concerned specifically with doses to humans and considers availability in those terms.

d) The subject of long-term health effects resulting from exposure to alpha particle radioactivity is under continuing review. The guidance is based on best available current information.

e) Production of plutonium, fabrication, and testing of weapons are necessarily carried out in areas restricted to the public. The Federal government purchased land for these specific purposes, including surrounding "buffer zone" areas.

51. Ilene Younghein

Section 1.3. Other modes of resuspension of airborne particles could be traffic, and plowing. "Discrete particles" is cosmetic language. Separate particles would be a better use of the language. No way can a particle of Pu 239 be called discrete. The statement that the uptake by plants is relatively small is misleading. Plants have been know to accumulate plutonium and concentrate it in their systems, and your statement that most animals, including humans have a high discrimination factor against transfer of these elements into body tissue is questionable. For sure, plutonium deposited on the skin can cause cancer.

Staff Response - a) Traffic and plowing are examples of man-made disturbances.

b) Discrete is not discreet (see dictionary).

c) The agency staff has considered all available information on plant uptake. No reference was found to substantiate concentration in plants.

d) Discrimination factors for biological uptake of ingested plutonium are based on best available information.

e) There is no evidence that plutonium deposited on the skin can cause cancer. Even if plutonium penetrated the skin the expected result would be development of a foreign body granuloma or fibroma. (See Lushbaugh, et al., Ann. N. Y. Acad. Sci. 145:791-797 (1967))

52. Ilene Younghein

The makeup of your Working Group is suspect. Both ERDA and NRC have and still actively promote nuclear energy. NASA uses nuclear satellities, and the Department of Defense is responsible for most of the contamination from the transuranic elements. Under the DOD we have gone from the average fallout of .06 pCi/g to 18,000 pCi/g in Nevada. This may be a reason for the high cancer rates in Nevada. Plutonium levels now measure 1000 pCi/g at Rocky Flats, Colorado. Cancer and leukemia rates have reached almost epidemic proportions in North Denver, and in Mesa County - home of the uranium tailings. Rather than try to cut down on radioactive contamination, the State of Colo. has accommodated themselves to it, and raised their levels of allowable pollution to twenty times fallout.

Staff Response - a) The function of the Working Group was to act in an advisory capacity and to make available to the EPA the technical expertise of these agencies. The Federal Radation Guidance is subject to interagency review and signed by the President.

b) The past or present association of an individual with nuclear energy or nuclear weapons is not considered a deterrent to his providing developing technical expertise relevant to radiation protection.

c) The statements referring to cancer and/or leukemia "epidemics", and the rationale for the current Colorado standard are irresponsible and not based on fact.

53. National Council on Radiation Protection and Measurements

The documentation and information used from the reference is frequently in error. There are a number of cases where the reference does not discuss the subject matter at hand. In several others, a review of the reference leads to conclusion different from those quoted. In at least one case, a qualitative statement was made about the results when a quantitative statement is needed to justify the conculsion.

We recommend a vigorous review of the references and the material used in the report in order to provide an accurate indication of the important material.

Staff Response - In the absence of more definitive information, no response can be provided for this comment.

54. N.Y. Federation for Safe Energy

The proposed guidance is incomplete in that it does not take into account the many sources of radiation individuals are exposed to due to industry and commercial uses of radioactive products, as well as additional radioactivity released from operating facilities such as Millstone and Fort St. Vrain, which are just two recent incidents that come to mind.

Staff Response - The guidance provides recommendations only for transuranium elements in the general environment. None of the sources terms mentioned are applicable.

55. Jefferson County Health Department

Why are dosage rates (page 17) expressed in terms of millirad per year (mrad/yr), since the term "rad" does not include the relative biological effectiveness factor for the type of radiation involved? The U.S. Environmental Protection Agency (EPA) water quality standards published in 1976, for example, give standards for exposure to radiation in millirem.

Staff Response - The Guidance limits are applicable to alpha particle emitters. Therefore both dose and risk estimates are expressed in a more fundamental physical unit, the rad, which is a measure of the specific energy imparted. This approach is more straightforward and periodic revision of the Guidance will not be needed to account for differences between various kinds of radiation. Further information on health effects will, however, be factored into these guides as the need arises.

3. RESPONSE TO COMMENTS ON ANNEXES I THROUGH VI

3.1 Annex I - Transuranium Elements in the Environment

Comments of an editorial nature were accepted where appropriate and will be reflected in future publications of this Annex. Reference 22 of Annex 1 should be changed to: Douglas, R.L. "Data Report - Levels and Distribution of Environmental Plutonium Around the Trinity Site," ORP/LV-78-3, USEPA, Office of Radiation Programs, Las Vegas Facility, Las Vegas, Nevada 89111 (1978).

1. Department of Energy

Although included in the list on p. I-1, the possibility of future accidents involving nuclear weapons and satellite power sources is not discussed. This is, based on past experience, a more probable "source for future release of the transuranium elements to the general environment" than "operations associated with the Light-Water Reactor Fuel Cycle." (p-1)

Staff Response - The relative probabilities of future releases from these sources are not well known but we agree that future uncontrolled releases to the general environment could occur from operations other than those associated with the Light-Water Reactor Fuel Cycle.

2. N.Y Federation for Safe Energy

Page 3 states the major portion of the transuranium elements in the environment is the result of nuclear weapons tests during 1945-63. Was 1963 the last nuclear test that was considered in total fallout? If so, the French test of 1976, the "dirty" Chinese tests of 1976 and 1977, should be included, as well as any radioactivity released by the Cosmos crash last month. (p-3)

Staff Response - Tables in Annex 1 include measurements on plutonium in fallout through 1975. Tests after 1975 have not significantly altered the environmental levels of plutonium in soil.

The evaluation of existing environmental contamination given in the technical documents is not intended to be exhaustive, but rather to give a summary of the current status. Inclusion of specific events is not pertinent to the intent and rationale of the guidance.

3. Department of Energy

The last listing in the inventory column, "4,000 (Pu-238)" is not correct. It was probably intended to be "4000 (Am-241)."

Staff Response - "4,000 (Pu-238)" should be changed to "4,000 (Am-241)."

4. Department of Energy

The relationship of the Tonopah Test Range to the Nevada Test Site should be clarified. (p-9)

Staff Response - The Nellis Air Force Range nearly surrounds the Nevada Test Site forming an exclusion area 25 to 100 kms wide (ref. 29, Annex 1). The Tonopah Test Range is located in the northwest corner of the Nellis Air Force Range and is not considered to be part of the Nevada Test Site.

5. Department of Energy

The old boundaries within the new boundaries of Rocky Flats are confusing and should be deleted or explained. (Fig. A 1-6)

Rocky Flats boundaries should be updated.

Further explanation is required for the numbers on this figure, some of which are isopleths and some of which are sampling locations.

More recent surveys show better estimates of these isopleths.

The statement that "plutonium in soil (offsite areas) is less than 0.1 uCi/m^2" is in apparent disagreement with Fig. A 1-7, which shows a 0.5 uCi/m^2 isopleth extending beyond indicated plant boundaries. An up-to-date version of Fig. A 1-7 might eliminate this problem.

Some attempt should be made to relate the 5 cm deep samples discussed here to the 1 cm deep samples of the Guidance screening level. It is otherwise possible to mistakenly conclude that the Rocky Flats samples could exceed the screening level.

Staff Response - An updated map of the Rocky Flats site showing the new boundaries and isopleths in units of uCi/m^2 is shown in fig. 2.4-24 of the "Draft Environmental Impact Statement - Rocky Flats Plant Site, Golden Colorado", ERDA-1545-D, (Sept. 1977). This is reproduced on the following page.

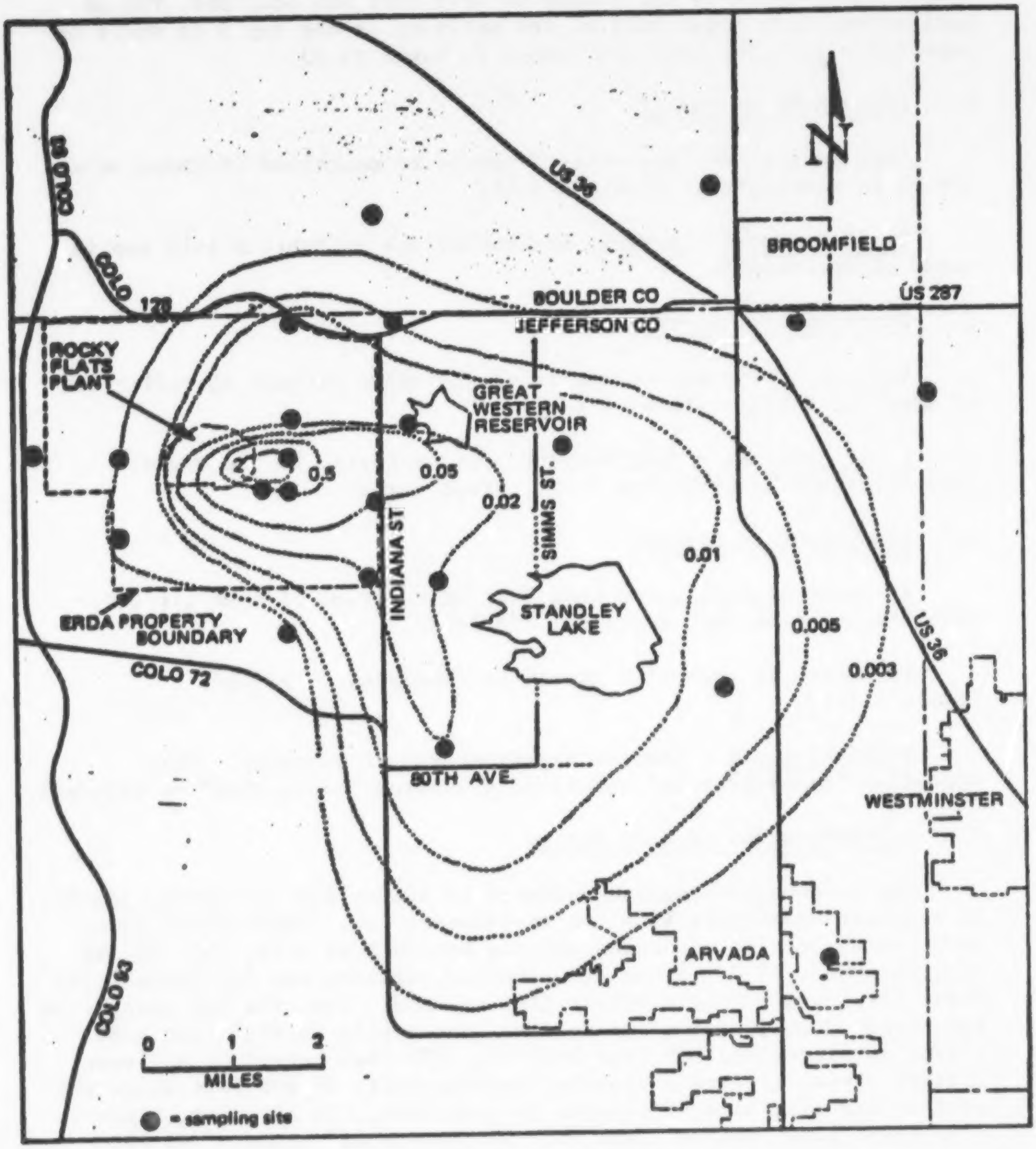
COLO 93
US 36
BROOMFIELD
COLO 128
BOULDER CO
US 287
JEFFERSON CO
ROCKY FLATS PLANT
GREAT WESTERN RESERVOIR
2
0.5
0.05
0.02
SIMMS ST.
INDIANA ST
0.01
STANDLEY LAKE
ERDA PROPERTY BOUNDARY
0.005
0.003
COLO 72
US 36
80TH AVE.
WESTMINSTER
ARVADA
COLO 93
0
1
2
MILES
● = sampling site

FIGURE 3 Plutonium-239 Contours Around Rocky Flats ($\mu Ci/m^2$)
(adapted from Krey, 1970)

The relationship between a 5 cm deep samples and a 1 cm deep sample will depend on the mixing of soil that has occurred. For an undisturbed site about half of the activity in the top 5 cm would be expected within the top 1 cm (Annex I, Table A1-2)

6. Department of Energy

"Wet weight" or "dry weight" should be specified if these values are to be meaningful. (Table A 1-10)

Staff Response - Average concentrations in Table A 1-10 are in terms of wet weight.

7. Department of Energy

Data on core sediment sample has no value without specification of sampling depth. (Table A 1-11)

Staff Response - Core samples were collected by the Mound Laboratory and are believed to be 1 foot cores.

8. Department of Energy

It would be helpful to know over what period of time air and rainwater samples were averaged. (A 1-12)

Plutonium in rainwater cannot be expressed in pCi/m^2. (Table A 1-12)

Staff Response - Samples represent annual averages. The plutonium "concentration" should be plutonium "deposition" in rainfall.

9. N.Y Federation on Safe Energy

The referenced proposed Guidance is incomplete in listing sources of radioactive materials in the environment now. Table A1-15 lists underground testing conducted off the Nevada Test Site, ref. US AEC Jan. thru Dec. 1973. Since the proposed guidance was not issued till Sept. 1977, why wasn't a recent listing used. Even the one that is in the proposed guidance is incomplete. One really "dirty" (and most likely embarrassing) NTS test Dec. 18, 1970 "Baneberry" is not even listed. This released a cloud of radioactivity 10,000 feet above the surface exposing some 86 persons to radiation. In addition, since 1973 there have been at least 40 - 50 "announced" tests. (A1-15)

Staff Response - Underground nuclear tests on federally owned sites have not released transuranium elements to off-site areas in quantities that lead to significant doses compared to guidance recommendations.

10. Department of Energy

Reference should be given. (Table A 1-24)

Soil data have no value without specification of sampling depth. (Table A 1-24).

Staff Response - References for Table A 1-24 and for Table A 1-25 are 10, 13, and 24.

The soil samples in Table A 1-24 were collected to 2.5 cms.

11. Colorado Department of Health

Throughout the supporting documentation regarding airborne concentrations of plutonium as related to soil contamination levels, only ERDA (now DOE) data has been used. Following the EPA hearing held in Denver on January 10, 1975, at your request the Department's air surveillance data for the Rocky Flats Plant environs was provided. On previous "rough" drafts of the proposed guidance document we have commented that data other than that provided by the ERDA facility have not been referenced or used. As the State's data identifies levels a factor of 2-8 higher than the values provided by the Rocky Flats Plant's own surveillance, you underestimate the associated health risk and the costs of remedial action. We urge your use of all pertinent data in your evaluation and assessment of the guidance impact.

Staff Response - Table 1 is a partial summary of some of the Colorado Department of Health data on air concentration levels of plutonium taken from "U.S. AEC Rocky Flats Plant 1971 Environmental Surveillance Summary Report" Colorado Department of Health, Division of Occupational and Radiological Health, Denver, Colorado, and succeeding volumes in this series through 1974.

The agency staff recognizes that the data reported by the Colorado Department of Health are generally higher than similar data reported by the Rocky Flats Plant. Such experimental differences may be indicative of systematic differences in the sampling and analysis methods, actual variations between sites, differences in measurement interval, short-term fluctuations, or other reasons. The accuracy and precision of environmental measurements is necessarily limited, and such constrants must be recognized. However, it is important to recognize that none of the data presented by the State of Colorado for offsite areas around the Rocky Flats site indicate that air concentrations of the transuranium elements exceed the agency's screening level. Therefore, few, if any, remedial actions are expected to be necessary for this site, and the costs have not been underestimated.

TABLE 1

Concentration of Plutonium in Air - Rocky Flats Site, 1971-1974
- Colorado Department of Health Stations -

Sample Location		Plutonium Concentration in Air 1971 (fCi/m³)	 1972 (fCi/m³)	 1973 (fCi/m³)	 1974 (fCi/m³)
On Site Stations East of the Plant	D-1	0.31	1.4	---	0.31
	D-2	0.34	0.69	0.59	0.72
	APC-56	1.8	2.3	---	0.17
	D-3	10.	4.5	2.9	3.8
	D-4	7.3	5.5	3.2	1.3
Local (b) Off Site Stations	APC-2	---	0.04	0.07	0.05
	APC-15	0.08	0.06	0.05	0.25
	APC-16	0.08	0.06	0.06	0.08
	APC-17	0.07	0.04	0.06	0.07
	APC-22	0.07	---	0.05	0.10
Remote Station	APC-29	---	0.08	0.14	0.07
	APC-42	---	0.06	0.07	0.13
	APC-81	---	0.07	0.23	0.32
	APC-108	---	0.11	0.05	0.14

(a) "USAEC Rocky Flats Plant 1971 Environmental Surveillance Summary Report" Colorado Department of Health, Divison of Occupational and Radiological Health, Denver Colorado, and also succeeding volumes in this series through 1974

(b) Located in Metropolitan Denver Area; to the east and southeast of the Rocky Flats Site

12. Jefferson County Health Department

This report states that "less than 10 microcuries of plutonium were released from plant stacks and vents to the atmosphere in 1975." However, on one day in 1957, an average of 948 picocuries per cubic meter were released from one stack to the atmosphere for a total amount of about 5,000 microcuries in one day (3). In considering the rezoning of agricultural lands adjacent to the plant site for residential use, such accidental releases of plutonium in such large amounts must be evaluated.

In the third paragraph on this page, reference is made to figures A 1-6 and A 1-7 which show plutonium values in soils to a depth of five centimeters. Why was a more recent report giving plutonium concentrations in respirable dust on the surface of the soil not cited, instead of this soil inventory figure (8)? It is noted that americium-241 within the site boundaries are about 10% of the plutonium-239 values. In a few decades, the americium will present as much radiation hazard as the plutonium. I'm not certain that this has been considered in calculating the guidelines.

Staff Response - The most significant releases of plutonium from the Rocky Flats Plant Site are still believed to be the result of leaking oil drums containing plutonium as a contaminant. However, surveillance measurements cannot distinguish between plutonium from stack releases or from the leaking oil drums. In practice, all plutonium in soil around the plant, regardless of the source, has been evaluated.

The measurement of plutonium concentrations in respirable dust has not yet been accepted as an appropriate measurement procedure useful for the estimation of hazards associated with plutonium in soil.

Americium-241 concentrations in soil and other environmental media were considered in the proposed guidance.

13. N.Y Federation on Safe Energy

I would question why, at sites listed in the proposed guidance, information is lacking, such as elements released to air (pg. 152) at Argonne National Lab., and (pg. 55) water at Oak Ridge Facilities . If EPA wants to set meaningful guidelines, Step One is to see where you are now. This cannot be done with speculative and/or partial information.

Staff Response - The agency staff believes that there is sufficient information on environmental levels of the transuranium elements to permit the issuing of Federal Guidance at this time.

14. **Ilene Younghein**

The Enewetak Islands not likely to be reoccupied were not named. p-51 "these high levels are believed to have been caused by analytical errors." Perhaps it would be wise to find out. p-54,55 finds soil samples taken at different depths making it hard to compare. Why was plutonium concentrations in water at White Oak Creek Clinch River not published. (p-46)

Staff Response - The information given is quoted from available technical reports. It is relevant only to the extent that is provides an indication of the existing environmental contamination levels at various sites.

3.2 Annex-II Environmental Transport and Pathways

1. Department of Defense

Department of Energy

An arrow head is missing between "water" and "sediments." (Fig. A 2-1).

Staff Response - Correction to Fig. A 2-1 is acknowledged.

2. Department of Energy

The implication that environmental plutonium will usually be present in oxide form has sometimes been assumed, but without proof. References for these statements should be given. (p.3)

Staff Response - Price and Ames have reported the presence of PuO_2 under both alkaline and acidic oxidizing environments. Their observations were made approximately 20 years after the acidic radioactive waste was disposed to the alkaline soils. Tamura inferred the presence of PuO_2 in soils from the Nevada Test Site. Theoretical studies by Polzer and Rai and Serne have predicted PuO_2 as the most stable plutonium compound expected to be present in soils.

ref:

S.M. Price and L.L. Ames, Characterization of Actinide-bearing Sediments Underlying Liquid Waste Disposal Facilities at Hanford, IAEA-SM-199/87, International Atomic Energy Agency, Vienna (1975).

T. Tamura, "Distribution and Characterization of Plutonium in Soils from Nevada Test Site," in The Dynamics of Plutonium in Desert Environment, NVO-142, USAEC, Las Vegas, Nevada (1974).

W.L. Polzer, "Solubility of Plutonium in Soil/Water Environment," in Proceedings of Rocky Flats Symposium on Safety in Plutonium Handling Facilities, CONF-710401, Dow Chemical Company, Rocky Flats Div., Golden, Colorado (1971).

D. Rai and R.J. Serne, "Plutonium Activities in Soil Solutions and the Stability and Formation of Selected Plutonium Minerals," J. Environ. Qual. 6, p.89 (1971).

3. Department of Energy

"In liquid form" is probably intended to mean "as a solution." (p-3, line 12)

Staff Response - Wording changed to read "as a solution."

4. Department of Defense

Department of Energy

A 10 um diameter particle does not have an AMAD of comparable size, thus it is unlikely that particles in this upper range would be termed respirable. (p-3)

A 10 um diameter particle of plutonium oxide will have an aerodynamic diameter of about 30 um, which is well beyond what is usually considered the respirable range. (p-3)

"wet and dry deposition" should be defined. (p-3).

Staff Response - We agree. The wording of lines 17-22 should read:

Airborne releases of the transuranium elements will generally be in the oxide form and contain a substantial percentage of particles within the respirable size range. Because of the small gravitational settling velocities of the respirable size particles, they can be transported long distances by air currents before attaching to surfaces or being removed by precipitation.

5. Department of Energy

Unnecessary detail about PuO_2 and hydrated PuO_2 may be confusing if not further explained. (p-4)

Staff Response - In future revisions of the document, details of the interaction of PuO_2 with soil particles will be transferred to Section 2.2. Soil Transport in order to minimize the confusion of the reader.

6. Department of Energy

It is implied that we can expect considerable progress in the understanding of resuspension phenomena as a result of recent studies. Actually, such studies have been conducted for many years and there has been no acceleration of work over the past several years. (p-4)

Staff Response - No such implication is meant. It is for this reason that the agency staff has selected to employ, with some modification, a relatively simple relationship for describing resuspension rather than attempt to incorporate many of the factors listed in Table A 2-1.

7. Department of Defense

Department of Energy

What is depicted in this table are not the "factors influencing wind suspension" but factors that influence the resuspension of materials by wind action. (Table A 2-1)

A better title would be "Factors Influencing Resuspension by Wind." "Meteorology," not "Meterology." (Table A 2-1)

Staff Response - The caption of Table A 2-1 should be changed to read "Factors Influencing Resuspension by Wind."

8. Department of Energy

The data summarized in this table are of little value without more adequate definition of the terms used and without more information concerning the circumstances under which the data were obtained. (Table A 2-2)

Footnotes could easily be mistaken for reference numbers.

Staff Response - The staff does not agree that the data summarized in Table A 2-2 are of little value. Unncessary details about experimental conditions would only confuse the reader. As discussed in the text, the purpose of Table A 2-2 is to provide the reader with a feeling for the range of resuspension factors, for newly deposited material. Measurements were made under conditions of wind and mechanical disturbance.

9. Department of Defense
Department of Energy

"over a period of time" is not clear. (p-8, line 20)

The very vague statements about solubilization of plutonium oxide should be referenced and placed in some more precise time frame than "over a period of time." (p-8)

Staff Response - Several mechanisms have been suggested (see references below) which can lead to increased solubilization of plutonium after its release to the environment. Included among these are: 1) chelation by organic constituents in the soil or through the addition of fertilizers, 2) increased root absorption zone contact as plutonium migrates down through the soil, 3) increased radiocolloid size due to aging, and 4) the long-term action of micro-organisms present in the soil.

Since much of the research into these mechanisms is in the early stages, a quantitative discussion of the time required for such transformations is not currently possible. However, preliminary data have not demonstrated a rapid transformation to occur under conditions generally encountered in the environment. It is most likely that, if these transformations occur at all, they would take on the order of years to decades.

ref:

J.M. Cleveland and T.F. Rees, "Investigation of Solubilization of Plutonium and Americium in Soil by Natural Humis Compounds," Env. Sci. Tech. 10, p.802 (1976).

E.A. Bondietti, S.A. Reynold, and M.H. Shanks, Interaction of Plutonium with Complexing Substances in Soils and Natural Waters, IAEA-SM-199/51, International Atomic Energy Agency, Vienna (1975).

E.M. Romney, H.M. Mork, and K.H. Larson, "Persistence of Plutonium in Soil, Plants, and Small Mammals," Health Physics 19, p.487 (1970).

W.V. Lipton and A.S. Goldin, "Some Factors Influencing the Uptake of Plutonium-239 by Pea Plants," Health Physics 30, p.425 (1976).

K.R. Price, "A Review of Transuranium Elements in Soils, Plants, and Animals," J. Envir. Qual. 2, p.62 (1973).

F.H.F. Au, W.F. Beckert, and J.C. McFarlane, Plutonium Uptake by a Soil Microorganism, Aspercillus Niger, NERC-LV-539-37, USEPA, Las Vegas, Nevada (1976).

10. Department of Energy

The relationship between specific activity and oxide solubility should be stated more specifically. (p-9)

Staff Response - Increased solubility of Pu-238 versus Pu-239 may be attributable to the fact that the alpha radiations from Pu-238 are more energetic than those of Pu-239. This may contribute to greater aggregate recoil or ejection of clusters of atoms from the surface of the particle.

11. Department of Energy

It is not at all certain that "the resuspension of soil particles...will be the principal mode of further environmental transport." It seems more likely that transport in unvegetated areas will be by saltation or surface creep, and water movement of sediments may be of primary importance in erosion areas. In heavily vegetated areas, water transport will probably be of primary importance. (p-9)

Staff Response - Mechanisms other than resuspension are also responsible for the environmental transport of radioactive particles, and on a mass transport basis are more important than resuspension. Emphasis was placed on the resuspension of soil particles because inhalation is generally the most important pathway for environmental plutonium. The staff does acknowledge that these other mechanisms should be discussed and perspective given to their potential impacts.

12. Department of Defense
Department of Energy

Aqueous Transport: Are these four points subjective determinations by EPA or do they result from referenced works? If so, state. (p-10)

The four points listed should be supported by references.

Staff Response - References:

Point #1

J.A. Hetherington, D.F. Jerries, M.B. Lovett, *Radiological Impacts of Releases from Nuclear Facilities into Aquatic Environments*, IAEA-SM-198/29, International Atomic Energy Agency, Vienna (1975).

K.C. Pillai and E. Mathew, *Plutonium in Aquatic Environments-Its Behavior, Distribution, and Significance*, IAEA-SM-199/27, International Atomic Energy Agency, Vienna (1975).

Point #2 and Point #3

H.D. Livingston and V.T. Bowen, *Contrasts Between the Marine and Freshwater Biological Interactions of Plutonium and Americium*, HASL-315, Health and Safety Laboratory, USERDA, p.I-157 (1977).

Point #4

V.T. Bowen, H.D. Livingston, and J.C. Burke, Distribution of Transuranium Nuclides in Sediment and Biota of the North Atlantic Ocean, IAEA-SM-199/96, International Atomic Energy Agency, Vienna (1975).

13. Department of Energy

"Concentration factor" requires definition (p-10, line 22).

Staff Response - Concentration Factor $= \frac{\text{pCi/kg (wet plant)}}{\text{pCi/kg (water)}}$

14. Department of Energy

The reference to Langham's "studies" at Thule is in error. There is no mention of Thule in this paper. (p-10)

Staff Response - Reference to Langham: USAF Nuclear Safety 65, p.36 (1970).

15. Department of Energy

The postulated "limited mobility for environmental transport" in aqueous systems does not take into consideration extensive data on transport of sediments bearing radioactive materials in the Tennessee and Columbia Rivers. Movement of plutonium on sediments has also been demonstrated in several estuaries. (p-11)

Staff Response - The staff agrees that the wording should be changed to reflect the fact that hydrological transport of plutonium contaminated sediments occurs in marine and freshwater ecosystems and has been responsible for transporting radioactive material as much as several miles from its point of initial release. Since the radioactivity is primarily associated with the bottom sediments, its radiological significance in terms of dose to man has been generally assessed to be small. As long as the water body is maintained at a fairly constant level and large areas of the sediment bed are not exposed and allowed to dry, thereby becoming a wind resuspension problem, the radioactivity committed to the water will be bound in a form which has little biological availability.

Department of Defense
Department of Energy

The PAID code is crucial to the derivation of the guidance, yet it is not published. Because of the complexity of aerosol physics, particle sizes and distributions, etc., it is really unfair to ask that the general radiation industry accept on faith the assumptions, parameters and other input used in the PAID code; it should be available for review. (p-12)

No description of the PAID code is given here, or in Annex III, and the only reference is to an unpublished document. Since the specific numerical basis for this Guidance is all derived from the PAID code, its unavailability prevents any verification of these numbers. (p.12)

Staff Response - The PAID code is available as: Plutonium Air Inhalation Dose (PAID), Technical Note ORP/CSD-77-4, USEPA, Office of Radiation Programs, Washington, D.C.

17. Department of Energy

It is implied that because the PAID code "assumes σ_g to be 1.5," it is never necessary to determine σ_g. Since measurement of AMAD provides the data required, σ_g should be calculated to determine whether it is reasonable to employ the PAID code to model the aerosol behavior. It would also be well to check the assumption of log-normality. (p-12)

Staff Response - Although measurement of AMAD does provide the information from which σ_g can be calculated, the ICRP Task Group on Lung Dynamics provided the deposition fractions for the three compartments of the lung as only a function of AMAD. The Task Group concluded that the deposition fraction was not a sensitive function of σ_g. For this reason σ_g is not a parameter in the PAID code.

The assumption of log-normality is not universally accepted and may be an oversimplification; however, the staff has adopted it for the following reasons:

1. the assumption is consistent with the ICRP Task Group Lung Model.

2. most field instrumentation which are simple, easy to operate and which provide size separation over a fairly wide range of particle sizes are not capable of providing sufficient resolution to clearly define bimodal or multimodal size distributions.

3. the limited size distribution data obtained in the vicinity of plutonium contaminated areas have been able to be fitted reasonably well by a log-normal distribution.

ref:

M.W. Nathans, W.D. Holland, and H.C. Shaw, The Size Distribution and Plutonium Concentration of Particles From the Rocky Flats Area, TLW-6111, Trapelo/West, Division of LFE Corporation, Richmond, Calif. (1971).

L.R. Anspaugh and P.L. Phelps, "Results and Data Analysis: Resuspension Element Status Report" in The Dynamics of Plutonium in Desert Environments, NVO-142, USAEC, Nevada Operation Office, p. 265 (1974).

18. Department of Energy

This is a confusing paragraph that should be revised or deleted. It is not made clear why the entire distribution need be measured, nor how it is possible to do this if all samplers have an "upper size cut-off." The reference to "resuspending soil" is confusing in this paragraph which is otherwise devoted to measurements in air. (p-13, line 14)

Staff Response - The reason for this admonition is the fact that most lung models in general use assume that the value of the ambient air activity (which is supplied as input to the particular model) is the total air concentration. These models then proceed to fractionate the total concentration among the various lung compartments. In order to be consistent with this assumption, measurement should encompass the widest range of particle sizes possible. The interested reader is referred to the following reference comparing the collection efficiencies of several commonly used methods.

ref: Wedding, J. B., McFarland, A. R., and Cermak, J. E., "Large Particle Collection Characteristics of Ambient Aerosol Samples", Env. Sci. and Tech., 11, p. 387 (1977).

19. Department of Energy

This is an over simplified interpretation of a very limited experiment. The field was small and the range of meteorological conditions limited. Sweeping conclusions based on this single experiment are hardly justified.

However, much higher exposures would have been inferred had EPA employed the data collected at 7.6 m from the edge of the field rather than utilizing the data collected at 30 m from the edge of the field. It is not necessarily true that an individual might not spend a great deal of time at the edge of the field, since farmhouses are often at the edges of fields.
(p-14, line 14)

Surrounding areas downwind would be expected to experience some increased exposure due to "these operations." The Guidance contains numerous sentences in which the word "significant" is employed without definition. (p-14, lines 20-21)

Staff Response - Ideally one would like to have more data encompassing other types of soils and different meteorological conditions before attempting a scoping calculation of this kind. However, there is a paucity of such data. This calculation was meant to put into perspective the relative impacts of wind versus mechanical disturbance of a field with surface contamination roughly corresponding to the screening level suggested in this Guidance. The air data reported for 7.6 meters from the edge of the field was not incorporated into the calculation because the authors had raised doubts as to the precision of that data: "the large means and standard deviations...for the sampler locations 7.6 m downwind from the edge of the field were caused by 3 high measurements out of 27."

Using the same data, Healy (ref. 37) has also attempted to analyze the impact of agricultural operations. His objective was to calculate the maximum soil concentration that would not exceed a skeletal dose rate of 500 mrem/yr after 70 years to an individual at the edge of a contaminated field. He concluded that 14 uCi/m^2 would be the maximum allowable concentration for a 1000 m wide field if plowing were performed 40 hr/year. Extrapolation of Healy's data to a field at the screening level of 0.26 uCi/m^2 results in a projected dose rate of 9.2 mrem/yr after 70 years or 0.5 mrad/yr (based on ICRP Publication #26). This dose rate is a small fraction of the 3 mrad/yr limit recommended in this Guidance and, therefore, would not present a serious risk to individuals in the vicinity of the field.

20. Department of Defense
Department of Energy

A subjective conclusion that cannot be supported. If a one-time cultivation results in a many-fold increase inhalation hazard, one could just as easily conclude that the second-time disturbance could also cause an increase. (p-14, line 18)

If the first cultivation cycle resulted in a 30-fold increase in air activity, it appears questionable to conclude that subsequent cultivation "should not lead to significant increases." (p-14, line 18)

Staff Response - The document did not conclude "that a one-time cultivation results in a many-fold increase in inhalation hazard." The analysis showed that, although the air concentration increased during the various agricultural operations, the yearly average concentration was increased by less than a factor of 2 for the tractor operator (over that from wind resuspension) and by only 10% at a location 30 meters downwind from the edge of the field.

21. Department of Energy

Assuming the maximum indicated resuspension fraction of 10^{-2}, passage of 100 cars would leave 37% of the original contamination on the road surface. Is this "a small fraction?" (p-15, line 3)

Staff Response - The conclusion that only a small fraction would remain after the passage of 100 cars was taken from the original paper of G.A. Sehmel. That conclusion, however, does seem to be an overstatement by the author.

22. Department of Defense
Department of Energy

Distinguish between "uptake" and "uptake factor" throughout the section. Is one actual amount and the other a percent of that available or what? (p-16)

Throughout Section 3.2 the words "uptake" and "uptake factor" are employed in an ambiguous manner. They should be replaced by more precise and carefully defined terms. (p.16)

Staff Response - "Uptake" refers to the amount of transuranium material retained within the plant or animal.

$$\text{"Uptake Factor"} = \frac{\text{pCi/g acceptor}}{\text{pCi/g donor}}$$

23. Department of Energy

The assumption that "foods from other areas not as highly contaminated will make up part of the diet" might not be true of a "critical segment" of small farmers and home gardeners. (p-17, lines 1-3)

Staff Response - The assumption that "food from other areas not as highly contaminated will make up part of the diet" was applied only to estimating annual intakes for the general population. It is true that farmers and home gardeners who raise crops for their own consumption on contaminated land may have higher annual intakes than the general population and would have to be considered as a "critical segment" of the population when applying this Guidance.

24. Department of Energy

It should be clarified that 1.6 pCi and 2.6 pCi are estimates of fallout plutonium absorbed from the gastrointestinal tract into the blood. The word "intake" might be misinterpreted as "ingestion." (p-17, line 5)

Staff Response - The above DOE statement is incorrect. According to ref. 28, "the annual intake during 1972 was 1.6 pCi, due to 35% to grain products, 20% each to vegetables, fruits, and meats, and less than 4% to dairy products. The annual intake in 1965 was estimated to be 2.6 pCi".

25. Department of Energy

The "extreme assumptions of soil consumption rates...required" should be defined. Pica in children is characterized by "extreme" behavior, as discussed at some length in ref. 37 of this Annex. Might these children not qualify as a "critical segment?" The importance of a more precise definition, in the Summary Report, of "critical segment of the exposed popluation" is emphasized by questions such as this. (p-17, lines 23-25)

Staff Response - Pica in children is not normal behavior and would persist for a relatively brief period of time. Such isolated cases do not constitute a "critical segment" of the population.

The intent of the Guidance is to limit the risk from chronic exposure to the transuranics to an acceptable level. In the case of ingestion, the limit is expressed as the 70 year bone dose rate of 3 mrad/yr. Although acute exposures can always be postulated which exceed the normal chronic exposure levels, these must be analyzed in terms of the projected 70 year bone dose rate. If such projections do exceed the 3 mrad/yr (70 year), then the intent of the Guidance is that remedial action should be taken.

26. Department of Energy

The reference to "short residence time of plutonium in the gastrointestinal tract" is confusing and should be deleted, since radiation dose to the tract from alpha emitters is not considered significant. (p-18, line 1)

Staff Response - Sentence changed to read: "However, for the pathway to be as significant as the inhalation pathway, extreme assumptions of soil consumption rates would be required. This is because of the low transfer of plutonium across the gastrointestinal tract and the radiation dose to the tract from alpha emitters is not considered significant."

27. Department of Energy

This sentence seems to say that a resuspension factor, based on repeated measurements over a long period of time, can be used to calculate concentrations in air from concentrations in soil. But if one has already measured the concentration in air in order to derive the resuspension factor, why would it be necessary to calculate a concentration in air? (p-19, line 7)

Rather than "areas" this sentence should refer to "points," since, by definition, the resuspension factor is based on a measurement in air and soil at one point. In addition to the "variability of the local meteorology," reference should also be made to variability in mechanical disturbance.

Staff Response - Oftentimes in assessing the potential hazard of existing contamination, resuspension data are available for several locations on a particular site. However, data will not exist for every point. The sentence in question refers to using such measurements in evaluating the locations on the site for which air data are not available. Whenever air measurements exist they are certainly preferred over any calculational relationship between air and soil. On the other hand, the Agency feels that it would not be in the interest of public health protection to postpone a decision on the necessity of cleanup because air measurements at every point are not available.

28. Department of Defense
Department of Energy

C.F. needs better definition particularly as to how it is influenced by the depth of sampling and soil density. (p-19, line 2)

This equation cannot be properly understood unless C.F. is better defined. An explanation should be given for the effect of depth of sampling and soil density, and how these effects are applied in C.F. (p-19, line 19)

Staff Response - C.F. is the factor which converts a soil concentration in units of activity/surface area to units of activity/weight of soil. This is accomplished through the use of the sampling depth and average soil density:

$$\frac{\text{activity}}{\text{surface area}} \times \frac{1}{\text{sampling depth}} \times \frac{1}{\text{soil density}} = \frac{\text{activity}}{\text{weight of soil}}$$

29. Department of Energy

It would be helpful to briefly mention the methods by which airborne particles are measured in the National Air Surveillance Network (e.g., height of measurement). Without such a description it is not clear whether or not these measurements have any relevance to the problem of transuranic inhalation. (p20, line 1).

Staff Response - Specific details as to methods of particle collection employed in the National Air Surveillance Networks are described in Fed. Reg. 36:22384-22385 (1971). Regarding the question of sampling height, no specific guidance is given as to the location of samplers. It must be assumed, therefore, that the data reported by the NASN is a composite of various sampling heights.

30. Department of Energy

This sentence, even with the explanation that follows, is not clear. (p-20, lines 10-14)

The sentence beginning "This fallacy" would seem to suggest that there is only one fallacy involved in the mass loading approach to resuspension. Not included is any discussion of the usually erroneous assumption that the particles measured in the air come from the contaminated area. This is least apt to be true for the most important (respirable) fraction. (p-20 line 10)

The derivation of the Enrichment Factor is presented here with no discussion of its theoretical inadequacies and its lack of experimental verification. Since there is no experimental support, for the applicability of this "Enrichment Factor," and since the correction which it introduces is small compared to other uncertainties in resupension estimation,, and since it introduces costly implementation problems, the Enrichment Factor should be abandoned. (p-26, line 17)

If retained, the assumptions implicit in the Enrichment Factor should be stated. These are: (1) All of the smaller particle sizes in the soil are resuspended with equal probability; (2) all of the soil particles in the air sample arise from the contaminated area. The last particles, once airborne, are fractionated in size by deposition and that the smaller particles can travel hundreds or thousands of miles. (p-26 line 17)

The "equilibrium" implied is more correctly stated as one in which the amount of material in each size range deposited should equal the amount of material in each size range resuspended over the area. Both deposition and resuspension rates change as a complex function of particle size and wind speed. (p-29, line 7-10)

The comparison made in this sentence is not a valid one, because the factor estimated from Equation 8 is in reality a soil resuspension factor, while those to which it is compared are radioactivity resuspension factors. It is one of the inadequacies of the mass loading approach that these two kinds of factors not directly comparable.

Department of Defense

Enrichment Factor: The enrichment factor section suffers from a lack of discussion on its shortcomings, the assumptions in it, and absence of experimental verification. Its desirability or utility is not established. (p-26)

Staff Response - The above comments seem to reflect a basic misunderstanding on the part of DOE and DOD regarding EPA's use of the mass loading approach and the enrichment factor. The agency staff wholeheartedly agrees with DOE and DOD fractionation of particle sizes occurs with resuspension. Particles in the small or respirable size range will be more susceptible to resuspension and will remain airborne longer than the larger diameter particles. This fractionation process will generate a distribution of airborne particles different from the distribution of the bulk soil and, therefore, the activity per weight of the suspended dust will be different from the activity per weight in the bulk soil. Depending on the way in which the activity is distributed across the size range of the bulk soil, there will either be an enrichment of activity per weight in the suspended dust or a reduction of the activity per weight.

If the activity is predominately associated with the smaller, more resuspendable soil particles, the suspended dust will have a higher activity per weight than the bulk soil and vice versa. In any case, it is unlikely that the activity per weight in the airborne material would be the same as that in the bulk soil.

The mass loading approach by itself is not capable of considering this fractionation effect and as such would predict the same activity per weight for suspended and bulk soil. Because of this, the agency staff has developed what it terms an "enrichment factor." The purpose of this factor is to modify the basic mass loading formula in such a way as to reflect the distribution of activity as a function of particle size and the differences in size distributions between the bulk soil and suspended dust.

Another point of confusion appears to be the context in which the mass loading and enrichment factor were applied in the Guidance. This calculational technique was used in the derivation of the soil screening level. The agency staff feels that this level is sufficiently low that costly monitoring of the inhalation exposure is not required when surface concentrations are at or below this value. In order to derive such a number on a generic basis and to insure that this level is safe, some conservative assumptions had to be made, e.g., it was assumed that the contaminated area was sufficiently large enough that the airborne mass loading could be attributed to the resuspension of soil from the contaminated area. The staff does not dispute the point raised by DOE that, at real sites, injection of suspended particles from noncontaminated areas can contribute to the mass loading. If injection of these particles is occurring, then the mass loading calculation would predict higher than actual airborne activity thereby, overestimating the inhalation exposure. For this reason, the Guidance recommends the use of site-specific data to assess the actual exposure hazard when soil concentrations exceed the screening level.

31. Department of Energy

The data of Table A 2-3 are not the only data, nor the most applicable data. Recent studies of Sehmel (ref. 39) show much poorer correlation between predicted and observed results. (p-20, lines 8-10)

Refernces to Anspaugh are incorrectly listed. (Table A 2-3)

More recent and more applicable data of Sehmel (ref. 39) should be presented if this data is to be used. (Table A 2-3)

The mass loading approach is said to be supported by references 30 and 31. It should also be stated that more recent studies (ref. 39) have not supported the mass loading approach. (p-26, lines 4-8)

Staff Response - From the above comments, it appears that the DOE staff attribute considerable importance to ref. 39 and its conclusion that the mass loading approach is not a viable predictive methodology. Because DOE relies so heavily upon this reference, it is necessary to point out some of the limitations and serious errors contained in that reference.

First of all, as the author points out "Caution should be used in interpreting these data. The ground surface contamination data are limited in quantity and were not necessarily obtained in the same areas where resuspension experiments were performed."

In addition to the uncertainties raised by the above statement, the EPA staff questions the way in which the author interpreted his data. The approach used was to make comparisons only on the basis of extreme upper or lower observed limits. No attempt was made to define an "average" case (e.g., the mean observed concentration) and make comparisons accordingly. The mass loading approach has been used in the past only to calculate annual average air concentrations and was used by EPA only in that context.

More importantly, the author's conclusion that the mass loading approach did not predict the observed air concentrations was based upon an apparently erroneous calculation. It appears that the calculated values in Table 6 of ref. 39 are in error by 6 orders of magnitude because units were not matched properly. As a result, the predicted values in Table 6 are too high. When the necessary correction is applied, the predicted and observed levels show better correlation. For the lower limit case of 27.73 ug/m^3, the total concentration (Pu-239) of respirable and nonrespirable particles is calculated to be 1.9×10^{-17} uCi/cm^3. This calculated value can be compared to the observed mean value of roughly 2×10^{-17} uCi/cm^3 (Figure 6 of ref. 39) or the lower observed limit of approximately 5×10^{-18} uCi/cm^3. Whether the sampling of the lower limit Pu-239 concentration coincided with the recording of the 27.73 ug/m^3 is impossible to say from the data as presented. However, it can be justifiably argued that, within the limitations of the data, correct interpretation should have yielded the opposite conclusion.

32. Department of Energy
Department of Defense

No evidence has been presented to support the conclusion reached in this sentence that this approach "would seem reasonable." It easily could be argued that the reverse is true.

The aged source could contain a greater proportion of the transuranics at greater depths in the soil profile and the resuspended surface layer presumed to constitute the particle loading of the air would less accurately reflect average soil content. (p-20, line 24)

Why does it "seem reasonable" that the error associated with using mass loading approach would be least in "old" soils. With time, it might seem reasonable that there are more transuranic elements at depths than at the surface, thus causing the reverse of what is depicted here. (p-20, last sentence)

Staff Response - The statement in question is based on the fact that plutonium after it has been in the environment for a period of time has generally been found to be associated with soil particles, rather than existing as discrete plutonium particles. This association is the result of various chemical and physical processes which are collectively termed "weathering." Once it is associated with the soil particles, the plutonium would be expected to resuspend in the same manner as the surface soil and, therefore,its resuspension can be related to the airborne dust loading. On the other hand, freshly deposited activity may be more easily resuspended compared to the bulk soil due to a higher percentage of plutonium particles in the smaller size ranges. The decrease in the resuspension with time of freshly deposited material is generally attributed to weathering.

The observation by DOE and DOD that there may be more activity at greater depths with the passing of time is not germane to the discussion. The Guidance considers the erodible surface to be the top one centimeter and relates only activity within that centimeter to the airborne concentration.

33. Department of Energy

It is incorrect to state that the resuspension rate approaches have "attempted to include in their formulations as parameters some of the physical forces which control the resuspension phenomenon." The Healy-Fuquay approach (ref. 32) to defining the rate was used because of the lack of empirical data at that time. Present emphasis should be placed on the more recent considerations, presented in ref. 37. (p-23, lines 7-9).

It might be noted that more recent calculations by Healy in ref. 37 did include variations in resuspension rate with wind speed. (p-24, lines 5-7)

Staff Response - The Healy-Fuquay approach (ref. 32) assumed that the rate of pickup of particles from a surface is directly proportional to the ratio of wind forces to gravity forces on individual particles. By taking the wind force on a particle to be proportional to the square of the wind velocity and the particle area exposed to the wind, an expression was developed for the rate of particle pickup.

34. Department of Energy

This sentence implies that there are formulations for predicting resuspension that have "general applicability." Actually, none have been demonstrated to have any "general applicability." (p-24, lines 21-24)

Staff Response

No such implication is meant and in fact the text clearly states "the general applicability of these formulations...has not been demonstrated."

35. Department of Energy

Some qualification is needed of the statement that the weight fraction of particles 10 um is small in most soils. The tabulation of published data in reference 37 shows that this fraction ranges from a few percent in sands to several tens of percents in loams. Perhaps undisturbed soil including aggregates is meant. Even here care must be taken because soils lose their texture under long drought conditions. (p-27 lines 2-4)

Staff Response - The basis for the statement in the text was data from sites of existing plutonium contamination where the less than 10 um weight fraction has been small. In certain soils, especially clays, this fraction can be larger.

36. Department of Energy

Methods for the analysis of particles within size ranges should be described or referenced. (p-27, lines 22-25)

Staff Response - Various methods of particle size fractionation are described in the technical literature. Since detailed implementation of the Guidance is left up to the responsible agencies, it is not appropriate to present such details lest it be misunderstood as the only acceptable method.

37. **Department of Energy**

Subscript "i" misplaced. p-28, line 19)

Subscript "i" misplaced. (p-29, line 1)

Staff Response - Typographical errors are noted.

38. **Department of Energy**

The parenthetical expression, "based upon certain assumptions regarding prevailing meteorology," seems inadequate to convey the factual information that the calculations employed annual wind roses with joint wind speed, direction, and stability. (p-29, lines 24-25)

Staff Response - Such details were not felt to be necessary. However, future revision will reflect this comment.

39. **Department of Energy**

An additional important assumption, not listed, is the assumption that ingestion is a neligible risk compared with inhalation. This sometimes questionable assumption may compromise the utility of the screening level concept. There would seem to be no reason why ingestion could not be considered as an additional factor in the derivation of and probably accommodated in the screening level, thus making it more a universally applicable concept. (p-30, lines 10-17)

Staff Response - Assessments of dose to populations surrounding transuranium contaminated locations in the U.S. have concluded that the principal exposure hazard is inhalation and that the ingestion pathway is of little consequence. For this reason, the agency staff derived the soil screening level on the basis of the inhalation pathway as being the limiting case. It is possible in the event of some future accident that the ingestion pathway could be of greater significance. However the staff did not consider it appropriate to derive the screening level for soil based upon a future occurrence at some hypothetical location. The wide variation possible in crops types and dietary habits makes such a generic derivation tenuous.

On the other hand, the agency staff has looked at the impact of the ingestion pathway on populations with various postulated dietary habits who are exposed to land contaminated at the screening level. Even for the situation of the serious home gardener, the dose rates are not projected to exceed the limits recommended in this Guidance.

40. **Department of Energy**

The value of 100 ug/m^3 needs to be more carefully evaluated and the exact context of Anspaugh's and Healy's use of this number described. (p-30, lines 21-25)

Staff Response - Anspaugh employed a value of 100 ug/m^3 for the airborne mass loading when calculating acceptable soil concentration applicable to the Enewetak Atoll. His choice of 100 ug/m^3 was based upon an evaluation of values reported at rural sites in the continental U.S. and Hawaii. Anspaugh concluded "this value should be quite conservative for the Enewetak Islands and, therefore, allows room for the uncertainty involved because the people themselves may generate a significant fraction of the total aerosol."

Healy concluded that a value of 120 ug/m^3 was sufficiently conservative in calculating limiting soil concentrations by the mass loading approach. His choice was based simply upon an interpretation of EPA's standard for airborne particulates .

41. **Department of Energy**

Additional justification is required for the use, as an average distribution over a 1-year period, of data measured by Chepil in a dust storm. (p-31, lines 4-6)

Staff Response - Regretably there is a lack of particle size distribution data covering the entire range of suspended sizes. Primary emphasis has been placed on the measurement and control of small particles (5 um) because possible deleterious effects can be better correlated with the smaller sizes and because these sizes are responsible for light scattering and visibility reduction. Few researches have reported data for the larger particle sizes. An effort was made in the text to compare Chepil's data with other sources and, within the limitations of the data, there was reasonable agreement.

42. **Department of Energy**

It is misleading to quote Sehmel's data as indicating "28% of the mass was below 10 um", when, in fact, 28% was the maximum value measured, under minimum resuspension conditions, and a value of 0.3% was measured for the greatest mass loading, during dust storm conditions. If use is to be made of this data it should not be used selectively. (p-31, lines 11-13)

Staff Response - The data selected from Sehmel's report was that which corresponded most closely with annual average mass loadings reported by the National Air Surveillance Network.

43. Department of Energy

Figure is not clearly titled or labeled, and it is not referenced. (p-32, Fig. A 2-3)

Staff Response - Figure A 2-3 is referenced and discussed on page II-31.

44. Department of Energy

The acceptable air concentration here employed for derivation of the screening level is based on an assumed AMAD of 1 um. In Annex V (p. 6), "the Agency suggests that such a derived air concentration limit be based on an activity median aerodynamic particle diameter (AMAD) not to exceed 0.1 um." This apparent discrepancy should be explained or eliminated. A reference at this point to the discussion in Annex V would seem appropriate. (p-33, lines 5-8)

Staff Response - There is no discrepancy in using a 1 um AMAD in calculating the soil screening level and use of 0.1 um AMAD for the air screening level.

In situations where contaminated soil is the primary source of the airborne activity, AMAD's of approximately 1 um have been reported. Whereas, when stack release are the primary source, much smaller AMAD's (approximately 0.1 um) have been observed. In deriving the soil screening level, which relates the airborne activity to the soil as the source, a 1 um AMAD was used. On the other hand, in the defining an air screening level where the source is unspecified the more conservative assumption of a 0.1 um AMAD was used.

45. Department of Energy

This Table requires a title and a reference and should presumably be A 2-4.

It is not clear what these data represent. Are RF 1A, 1B and 1C aliquots of a single sample? What area is represented by these samples? How were the sizes determined? Do they include aggregates? What was the season of the year and the moisture content when sampled? Can the results be reproduced if another sample is taken? These questions are all important if the data are to be understood. (p-34, Table A 2-3)

Staff Response - Table A 2-3 on page II-34 should be renumbered as Table A 2-4.

Reference for Table A 2-4 is: D.E. Bernhardt, Evaluation of Sample Collection and Analysis Techniques for Environmental Plutonium, ORP/LV-76-5, USEPA, Las Vegas, Nevada.

Specific details of the sampling and analysis methodologies are described on pages 20 through 45 of the above reference.

46. Department of Energy

If resuspension values have been reported for "existing sites" it would seem important to list and reference them in the Annex. Are these annual average factors or single measurements? (p-35, lines 6-7)

Staff Response - Anspaugh (ref. 30) reported resuspension factors of $3\times10^{-9}m^{-1}$ and $2\times10^{-9}m^{-1}$ as a result of 17 months of measurements at the Nevada Test Site.

Rodgers (ref. 4) reported a resuspension factor of approximately $10^{-9}m^{-1}$ for the vicinity of Mound Laboratory based upon 3 years of data.

Healy (ref. 37) calculated a resuspension factor of $2\times10^{-9}m^{-1}$ for the Rocky Flats Plant site based upon 4 years of reported data.

47. Jefferson County Health Department

Environmental transport and pathways. On page 4, reference is made to the work of Tamura, who has shown that plutonium bound to fine particles (2-5 microns) was present as hydrated plutonium oxide. Is hydrated plutonium oxide more likely to be taken up from the intestional tract? I note in the last paragraph on this page that "such a wide range of values makes prediction of the resuspension factor for a particular set of conditions a difficult task." The guidance implies here that there is a variation of perhaps 100. Elsewhere in the EPA guidance, a variation factor of one million is cited. This order of variation makes the use of such a resuspension factor questionable.

Staff Response - Hydrated plutonium oxide is not more likely to be taken up from the intestional tract. For example, $Pu(OH)_4$ has been reported to have a solubility constant of 7×10^{-56} which is indicative of a high degree of insolubility.

The staff did not make use of the resuspension factor approach in developing its guidance levels because of the wide variation in reported resuspension factors. The range which is quoted as 10^6 covers virtually all reported values for the resuspension factor regardless of the experimental conditions. Many of these were obtained under conditions not applicable to environmental conditions. When these values are removed from the data set, a narrower range of values is obtained. The resultant range is still too large, however, to be useful in developing a generic resuspension factor.

48. Jefferson County Health Department

Soil transport (page 8). This report states that plutonium dispersed on the soil "has a tendency to bond chemically and/or physically with the soil." Why then did the plutonium become airborne from the soil containing plutonium in cutting oil at the plant site? The report further notes that plutonium oxide is "generally considered to be insoluble", but "can undergo dissolution in neutral aqueous media." The plutonium oxide particle dissolves producing plutonium ions until the formation of a hydrated coating inhibits further dissolution." "Plutonium ions formed during the dissolution can undergo ion exchange reactions with the oxygenated ligands commonly found in soil (e.g. silicates), and become sorbed onto the soil, or react with other agents present in the aqueous phase and form soluble complexes." Since plutonium ions are able to displace most cations such as calcium, magnesium, sodium, etc., it would seem that such plutonium compounds would be available for uptake by plants. The ability of seaweed to concentrate plutonium with a concentration factor of about 1,000 is noted on page 10. Algae also have this ability.

Staff Response - The plutonium did not become airborne from the soil but along with the soil as a result of soil resuspension due to wind erosion and mechanical disturbance.

Plutonium ions have been found to bond strongly with the soil matrix through the displacement of other cations. This tendency to bond with the soil matrix is one reason for the slow migration of plutonium through soil and its low uptake by plants.

49. Jefferson County Health Department

The section on inhalation notes on page 13 that "when the aerosol being sampled contains large particles of activity associated with them, the gross air activity being measured may be underestimated" and "if particles from the resuspending soil have disproportionate amount of activity associated with them, the inhalation hazard could be underestimated."

Staff Response - The above statement was taken out of context. It refers to the fact that air sampling, in order to be compatable with the mathematical models describing lung deposition, must be operated to collect the widest range of particle sizes possible.50. **Jefferson County Health Department**

Enrichment factor (page 26). In reference to the use of respirable dust samples, the report states at the top of page 27, that "however, the weight fraction of particles in the less than the micron range is small in most soils, and sampling, separation, and analysis techniques are correspondingly more difficult and inaccurate." This is incorrect, since we found that this fraction can constitute as much as 62% of surficial soil. This sampling and separation procedure was developed with the assistance of soil scientists with doctoral preparation in this area (8,9). As the guidelines acknowledge, the hazard presented by plutonium oxide in soils is primarily due to inhalation. To use other than a respirable surface dust sample will give misleadingly low values. It is not possible to relate in any consistent manner the proportion of the respirable fraction to the surface soil. This is understandable, since the proportion of windblown material retained at any specific site will depend upon topography, vegetation, the strength of prevailing winds and many other factors. The best way to evaluate the hazard is by use of a surface respirable dust sample, which will provide consistent results from season to season and site to site. Calculations based on the questionable assumptions used in this and other sectins have little value, in my opinion.

Staff Response - The chemical analysis used by Dr. Johnson in soil sampling was purposely designed to destroy the cementing agents and grain coatings that bind small particles into microaggregetes, thereby altering the form in which they actually exist in the environment. A detailed critique of Dr. Johnson's proposed respirable size sampling method is contained in Chapter 7 of this document.

51. **Representative Timothy Wirth**

I think that the enhancement factor approach that was used to correct the "mass loading" assumption will tend to make the results more valid, but it seems to me that more research needs to be done on this problem. Not only the "mass loading" approach an equilibrium approach -- which may need to be corrected for nonequilibrium effects in order to become a more realistic model -- but the entire issue of respirable particulates, and the weight that should be given to them, must be dealt with better as well. This implies no criticism of the EPA's effort. I am sure that the model used is the best now available. But I think that the model should be improved upon, and periodic adjustments in the standards, and site analysis should be undertaken as those improvements occur. An EPA commitment to undertake those improvements and modifications or guidelines would go a long way to reassuring the populace around Rocky Flats that the best possible theories are being used to ensure their safety.

Staff Response - The mass loading approach is an averaging over many "non equilibrium" conditions which can occur during the course of a year. It is recognized also that there are localized disturbances which would not be reflected in the general mass loading level. The agency staff has attempted to scope the impact of such localized disturbances (see Annex II) and concluded that the soil screening level is sufficiently conservative in these situations.
The Guidance is a recommendation on dose limits for transuranium elements. The screening levels for air and soil are administrative in nature and are only for the purpose of identifying areas where remedial actions may be necessary. Site-specific data should be collected and the potential pathways analyzed in order to determine whether remedial action is required.

The agency staff concurs that, if significant new information should become available in the future, changes in the Guidance would be appropriate.

52. Representative Timothy Wirth

I think that the analysis of the dust problem could be refined by further research. Is the distribution of radio-active elements in the dust the same per unit weight as in the top cm. of soil, or are there differences both in total dose/gm. and in the size distribution of it, for example.

Staff Response - There should be a difference in the activities per gram of suspended dust verses the activity per gram of the total soil. The activity per gram of the airborne dust can either be enhanced or diminished depending upon the way in which the activity is distributed in the parent soil. If the activity is primarily associated with the larger, less resuspendible soil particles, the activity per gram of the suspended dust would be lower; if the activity is associated with the smaller soil particles, the resuspended material would have a higher activity per gram than the parent soil.

3.3 Annex III - The Dose and Risk to Health Due to the Inhalation and Ingestion of Transuranium Elements

1. Dr. Edward Martell

Organ burdens of fallout plutonium in the general public have already reached levels of (approximately) 0.5 pCi/kg in lung tissue, (approximately) 0.7 pCi/kg in the liver, and comparable levels in the gonads and other organs (Moss and Campbell, 1972). Depending on the microdistribution of this alpha activity in the gonads and at tumor sites and on the mechanism of cancer induction, this fallout level of alpha activity may be contributing substantially to the rising general incidence of cancer and genetic effects in man. If so, exposure of large sectors of the general public to 200 times higher levels would have tragic consequences. Based on present knowledge, the only responsible recommendation regarding public exposure to insoluble alpha emitting particles would be that such exposures be restricted to the practical minimum. That practical minimum is, unfortunately, the level of fallout plutonium in surface soils.

Staff Response - The data for fallout plutonium in tissue used by Dr. Martell are taken from LA-4875, Plutonium in Autopsy Tissue. It was later discovered that a standardization error invalidated most of these measurements. The 1972-73 data reported by the same group in WASH-1359, Plutonium and Other Transuranium Elements: Sources, Environmental Distribution and Biomedical Effects are more reliable and report somewhat smaller organ burdens. More important, both data sets have a high degree of measurement errors and considerable variation between different individuals. As described in Annex 3 of the Technical Summary, they do not provide a means for estimating organ burdens with confidence.

The Agency's analyses show that the number of persons likely to be exposed at the proposed limit is small. Contrary to Dr. Martell's statement, it is not anticipated that "large sections of the general public" will be exposed to limiting dose values. The setting of Federal guidance at a dose level corresponding to average background radiation levels disregards the uneven distribution of plutonium in the environment and the costs required to return nature to a pristine state.

2. Dr. Edward Martell

In the production of chromosome aberrations the biological effectiveness of high-LET radiation is independent of dose rate and is much greater than that of X-rays and gamma rays (low-LET radiations), particularly at the low intensities of natural background radiation.

Upton has pointed out "Under conditions of low-level irradiation most pertinent to environmental carcinogenesis, therefore, the oncogenic potency of high-LET radiations is generally assumed to be relatively high, i.e., 10 to 20 times that of X and gamma rays" (Upton, 1967). There is growing evidence that the RBE for somatic mutations induced by high-LET radiation at the low dose rates applicable to background radiation are even larger, with RBE values ranging from 35 to 100 (Davis and Bateman, 1963; Neary et al., 1963). This is consistent with the long term repair of mutations induced by low-LET radiation and the resistence to such repair for mutations induced by high-LET interactions (Curtis, 1966).

Staff Response - RBE values were not used to assess cancer risks in the proposed guides. Rather, the hazards from alpha radiation were assessed directly from human effects data. For genetic mutations an RBE of 100 was used. This is consistent with the upper range considered by Dr. Martell.

3. Dr. Edward Martell

Insoluble alpha emitting warm particles (i.e., colloidal thorium oxide and uranium metal dust) have been demonstrated to be highly effective in lung cancer induction in mammals and man (Suckow et al., 1961; Heuper et al., 1952). By contrast, inhalation exposure to high levels of radon and its short-lived daughters was singularly ineffective in promoting lung tumors in mammals but gave raise to life shortening and other effects (Morken and Scott, 1966). Such apparently disparate effects for inhaled alpha emitters are readily reconciled on the basis of the "warm particle" hypothesis (see below) which implies a high cancer risk only for insoluble alpha emitting particles which persist in small volumes of tissue and give rise to alpha interactions with cell at frequencies which optimize the multiple mutation process. The results of Morken and Scott suggest that, at highly elevated levels of natural alpha activity (which is soluble in body fluids), the critical somatic cells which determine life span usually receive excessive radiation damage before the multi-stage process of lung cancer induction is completed.

Staff Response - The Morken and Scott article referenced by Dr. Martell is outdated. Chameaud, et al., (J. Chameaud, et al., pp.411-421 in Experimental Lung Cancer, Springer-Verlag, 1974) showed that, for rats, at least, nearly pure ^{222}Rn and ^{222}Rn with daughters produced adenomas and carcinomas equally well with and without uranium ore dust while the uranium ore dust alone was unsuccessful in inducing either adenomas or carcinomas. The "warm particles or clusters of particles" of uranium ore dust seem singularly unsuccessful in inducing tumors in this test system.

4. Dr. Edward Martell

The foregoing considerations indicate that, of the various sources of ionizing radiation to which man is exposed, internal alpha emitters merit special attention with regard to their possible role in the etiology of human cancer. The fact that particulate alpha activity in the lung gives rise to cancer, whereas, uniformly distributed alpha activity associated with elevated levels of radon results in life shortening with no cancers clearly indicates that the practice of averaging the organ burden and the radiation dose for internal alpha emitters is unjustified. It is obvious from these considerations alone that the incidence of alpha radiation induced cancer must be highly dependent on its distribution. It also follows from these considerations that the linear hypothesis of carcinogenic response to radiation is not applicable to the assessment of cancer risks from alpha radiation. The mounting evidence which indicates that insoluble alpha emitting particles which persist in tissue may be implicated in the etiology of bronchial cancer in cigarette smokers is briefly reviewed below.

The possibility that the alpha emitting radioisotope polonium-210 may be involved in the etiology of bronchial cancer in cigarette smokers was first proposed by Radford and Hunt (1964) and relatively high concentrations of polonium-210 were found in the bronchial epithelium of low lobe bifurcations in cigarette smokers (Little *et al.*, 1965). More recently it was found that radioactive lead-210, the 22 year halflife grandparent of polonium-210, is highly enriched on tobacco trichomes and in the unsoluble smoke particle formed by the combustion of trichomes in burning cigarettes (Martell, 1974). The presence of elevated levels of lead-210 as well as polonium-210 at the bronchial tumor sites of cigarette smokers has been confirmed (Radford and Martell, 1977). It has been pointed out that the insoluble radioactive smoke particles which persist in tissue would be very effective agents of cancer if the mechanism of alpha radiation induced cancer proceeds via a multiple mutation process (Martell, 1975). A multi-step process of alpha radiation induced cancer, referred to as the "warm particle" hypothesis, is described briefly below and in attachment #1 (Martell, 1977).

The hypothesis of alpha radiation induced lung cancer, briefly described in attachment #1, provides a preliminary consideration of the sequence of events which may be involved in the induction of bronchial carcinoma in cigarette smokers. It involves a four stage, multiple mutation process, as follows:

Stage 1: The slow accumulation of insoluble alpha emitting particles in damaged bronchial tissue. This process is markedly influenced by physical and chemical cofactors which damage the bronchial epithelium and thereby enhance the uptake of particles.

Stage 2: The production of premalignant cells by alpha radiation induced mutations. Most of the mutations induced by alpha interactions are either lethal or have adverse mitotic effect. The latter are eliminated by selection over successive cell generations. The premalignant cell is conceived to be a transformed cell with any of a variety of and/or combination of structural changes which give it a proliferative advantage over normal cells. It is proposed that premalignant cells have normal mitotic controls and normal mitotic rates but survive longer to divide a greater number of times than normal cells.

Stage 3: The selective proliferation of premalignant cells in limited clones. This process proceeds at a stimulated mitotic rate, driven by the relatively high rates of lethal alpha interactions in the environs of warm alpha emitting particles. This process can be stimulated by other agents which kill cells and thereby enhance mitotic activity.

Stage 4: Malignant cell formation by an alpha radiation induced change in any one of the premalignant cell which results in its loss of normal mitotic controls. This is the fully malignant stem cell which undergoes rapid, uncontrolled proliferation to form a tumor.

The first three stages of the proposed sequence of events proceed concurrently. The induction of additional structural changes in premalignant cells and in the outgrowth stem cells also is a continuous process which can explain the wide variety of kayotypes in lung tumors, the occurrence of multiple stem cells in some tumors, etc. Thus, insoluble alpha emitting warm particles which can accumulate and persist in damaged bronchial tissue, and perhaps at other tumor sites as well, provides a carcinogenic agent capable of inducing the cytogenetic changes observed in bronchial carcinomas and most other malignant human tumors (see Atkin, in German, 1974).

The warm particle hypothesis indicates a lung tumor incidence proportional to the duration of smoking in years to the fifth power, consistent with the best epidemiological evidence (Doll, 1971). The proposed mechanism also involves a mitotic activity dependence term and thus provides a basis for explaining the surprisingly similar incidence of common tumors in mice and men (Brues, 1959).

A key point in the warm particle hypothesis, and one apparently not considered heretofore by radiobiologists, is the critical point of transition between "warm" and "hot" alpha emitting particles which depends on the frequency of alpha interactions with cells and the cellular response. To optimize the multiple mutation process in small cell populations, the frequency of alpha interactions should not exceed about one critical hit per cell per day, the approximate time required for a mitotically stimulated cell to proceed through the complete mitotic cycle and divide. This transition point is approximately 0.01 picocuries of alpha activity per particle, the upper limit for warm particles.

Perhaps the most important implications of the warm particle hypothesis are that natural alpha activity in its natural form has negligible carcinogenic risk and that the carcinogenic risk from insoluble alpha emitting particles that persist in tissue is highly dependent on the alpha activity per particle, on the microdistribution of such particles, and on the properties of the target cells.

Staff Response - As noted in the response to the previous comment, recent experimental tests have failed to show a high carcinogenic response to warm particles. In the absence of bioeffects data to support the "warm particle" model, it must be considered spectulative. Moreover, many aspects of Dr. Martell's model for lung cancer induction are based on dated references with little consideration given to current models of carcinogenesis. In particular, Knudson (A. G. Knudson, Jr., pp. 45-52 in Origins of Human Cancer, Cold Spring Harbor Laboratory, 1977), Anderson (D. E. Anderson, pp. 39-54 in Persons at High Risk of Cancer Academic Press, 1975) and Kersey and Spector (J. H. Kersey and B. D. Spector, pp. 55-67, Ibid) have considered mutational models in the light of genetic predisposing conditions. Knudson, in particular, concluded that either 2 or 3 events are necessary to produce a cancer, with 3 event cancers usually being karyotypically abnormal. Recent reports indicate that the oat cell carcinoma of the lung, the carcinoma usually associated with lung irradiation, is karyotypically abnormal, with marker chromosomes (E. R. Fisher, et al., Am. J. Clin. Path. 69: 165-172 (1978).

Moreover, additional work is needed to confirm obervations and identify sources of ^{210}Po and ^{210}Pb before the assumptions of Martell may advance to the hypothesis stage. Although assumptions made by Dr. Martell concerning the distribution of Pb^{210} and Po^{210} in smoke and smokers may be consistent with the work of Radford and Martell (1977), they remain only assumptions, and extensive work would be necessary to prove and expand the preliminary findings. Other sources of Pb^{210} and Po^{210} must be investigated in addition to smoking. Many of the sources that may contribute have already been identified by Moore, Martell, and Poet (1976). For example, short term inhalation of dust while raking and bagging leaves might lead to deposition of particles with Po^{210}/Pb^{210} ratios of 0.4., equivalent to ratios seen in "smokers".

While Dr. Martell's model is interesting and bears watching, it is not quantitative and is likely to undergo extensive modification as it evolves into a less speculative model of cancer risk. It definitely cannot be used in standard setting in its present form.

5. **Dr. Edward Martell**

The proposed EPA guidance is based on the assumption "that the risk at any given low dose level is directly proportional to the damage actually observed at much higher dose levels." Such an assumption is particularly inapplicable to internal alpha emitters and can lead to an underestimation of the cancer risks for insoluble alpha emitters by factors of hundreds to thousands or more, for reasons briefly considered here.

Many of the important limitations of the linear hypothesis were reviewed by Brues (1958, 1959). With reference to multiple mutation mechanisms like that proposed by Armitage and Doll (1957) which is reconciled with the age-incidence of cancer in man, Brues (1958) comments, "This, if applied to radiation, would imply an exceptional effectiveness of widely spaced dosages, which does not appear to have been observed." I must comment that one cannot observe what one does not look for. It is proposed that insoluble "warm" alpha emitting particles which persist at tumor sites, give rise to malignancy via a multiple mutation process (attachment #1). Insoluble warm particles which accumulate and persist at human tumor sites appear to me to be the exceptionally effective radioactive carcinogens that Brues and others have overlooked. As noted above, warm particles may be expected to give rise to cancer risks several orders of magnitude higher than that for the same alpha dose from hot particles, and the risks attributable to natural alpha emitters which are soluble in tissue are neligible. Thus, the warm particle hypothesis is completely at odds with the linear hypothesis and indicates that the carcinogenic response is highly dependent on the spatial distribution of the alpha activity and the alpha activity per particle (or, alternatively, on the frequency of alpha interactions with the target cells). The warm particle hypothesis and other possible multiple mutation models can be tested experimentally. It is very important that we do so.

The results of Morken and Scott (1966) discussed above (comment 3) also are at odds with the linear hypothesis but are readily reconciled with the warm particle hypothesis. These results imply that, to be most effective for tumor induction rather than life-shortening, elevated levels of alpha radiation should be restricted to a small tissue volume in the organs at risk. On this basis, small populations of insoluble alpha emitting particles which persist in small volumes of tissue sites would appear to have exceptional carcinogenic potential.

The practice of averaging alpha activity burdens and doses for each organ, usually necessitated by lack of adequate information on the microdistribution, has futher compounded the confusion with regard to the biological end effects. The average alpha radiation dose for an organ or tissue volume, in which many of the cells are not irradiated at all and others are killed by an excessive number of alpha interactions, is a completely unreliable index of effects. Even when the high-LET irradiation pattern is known, the biological effects are still not a simple function of dose adjusted by an arbitrary quality factor, as Katz and Sharma (1974), Brustad (1961) and others have pointed out.

On the basis of the foregoing considerations, the basis of risk estimates for the proposed guidance is hopelessly inadequate and, for a multiple mutation process of cancer induction, grossly underestimates the risks for alpha emitting warm particles.

Staff Response - Dr. Martell's contention that the linear hypothesis underestimates risk by orders of magnitude is not supported in this argument nor by animal data. Experiments by Chameaud *et al.*, (J. Chameaud, *et al.*, pp. 411-421 in *Experimental Lung Cancer*, Springer-Verlag, 1974) show that, in rats, even filtered radon-222 (an almost pure diffuse alpha dose) can cause lung cancer and the more homogeneous the dose the greater the risk (J. Lafuma, *et al.*, pp. 43-53 in *Radiation Protection in Mining and Milling of Uranium and Thorium*, ILO Geneva, 1976). Similar results have been obtained in Syrian Hamsters by Anderson, *et al.* They found localized irradiation both alpha and beta, is less tumorogenic than diffuse exposure (E. C. Anderson, *et al.*, pp. 10-14 in LA-6898-PR, 1977). These animal data are contradictory to Dr. Martell's suggestion that the risk is underestimated because of special spatial dose considerations for "warm particles.":

The argument that the use of the 1972 BEIR report risk estimates is an underestimate of the risk by orders magnitude is not supported.

6. Dr. Edward Martell

Reports of the Advisory Committee on the Biological Effects of Ionizing Radiation (National Academy of Sciences, 1972 and 1976) have a number of serious shortcomings with respect to the assessment of the distribution of internal alpha emitters and their genetic and somatic health effects as follows:

a. Internal dose: The contribution of inhaled and ingested alpha emitters from natural and pollutant sources to the internal radiation dose at most critical soft tissue sites in mammals, including man, have not been determined. The limited published data on the distrubution of polonium-210 and radium-226 indicate wide variations in their concentrations from organ to organ and within each organ. What is the dose contribution at various soft tissue sites for the 11 natural alpha emitters: thorium-228, radium-224, radon-220, polonium-216, bismuth 212, polonium-212, radium-226, radon-222, polonium-218, polonium-214, polonium-210? These radioisotopes are present in some industrial plumes (Poet and Martell, 1977) and inside buildings, depending on construction materials and other factors. The added contributions of particulate alpha emitters from industrial and fallout sources (polonium-210, uranium and thorium compounds, plutonium-239 and americium-241) and their microdistribution in mammal organs merit particular attention.

b. Genetic effects: Contributions of internal alpha emitters to the spontaneous mutations rate and to the genetically significant radiation dose have not been determined. Because of the exceptional effectiveness of alpha emitters in the production of chromosome aberrations, it is essential to assess their concentrations at the germ cell sites. Relatively high concentrations of polonium-210 have been found in the sperm of cigarette smokers (Hunt, 1973) and Green *et al.*, (1975) reported higher concentrations of plutonium near the sperm sites than elsewhere in the tests. The presence of insoluble alpha emitting particles at the germ cell sites is a disturbing possibility that must be investigated experimentally.

c. Cancer risks: The microdistribution and micro-dose distribution for insoluble alpha emitting particles at human tumor sites, and the cancer risks attributable to such particles on the basis of multiple mutation processes, have not been assessed by the BEIR Committee. The possible role of alpha emitting "warm particles" in the etiology of bronchial cancer in smokers is discussed briefly in attachment #1 (Martell, 1977). Because alpha emitters are exceptionally effective agents for the production of the gross chromosome aberrations that are present in most human tumors (German, 1974), the possible presence of warm particles at other common tumor sites also should be investigated.

d. Atherosclerosis: Insoluble alpha emitting particles may be implicated in atherogenesis (Elkeles, 1977; Martell, 1975). This important possibility merits serious attention by the BEIR Committee and the National Institutes of Health.

Staff Response - The extent to which the NAS-BEIR Committee may incorporate Dr. Martell's suggestions into their current updating of their 1972 Report is unknown. His views were presented to the Committee at his request in July 1976. In the past the Committee has based its risk estimates on observed effects occurring to persons in irradiated groups. The Agency agrees that the role of alpha-emitting particulates is an important public health question and that the microdosimetry of these materials is essential to an understanding of their potential impact. Where data is available on this point, it was incorporated into the Agency's estimates of the risk from transuranium radionuclides.

The question of the contribution of "warm particles" to hazards in solid organs must be deferred until such particles have been indentified in organs and in areas of interest.

The relationship of atherosclerosis and "warm particles" is at best very tenuous. The co-deposition of calcium and alkaline earth elements is well documented. Calcification in fat and calcification in necrotic and injured cells in the body is also well documented. The finding of deposited alpha emitters in atherosclerotic lesions may not be significant. The "warm particles" certainly do not fit easily into the picture of atherosclerosis pathology developed by French (J. E. French, Intern. Rev. Exper. Pathol. 5:253-353 (1969).

7. Dr. Edward Martell

The foregoing discussion indicates that the proposed guidance is based on hopelessly inadequate information on the internal distribution of alpha emitters and their genetic and somatic effects. Additionally, the assumptions and models used as the basis of risk assessment are highly questionable and may lead to very substantial underestimation of cancer risks and genetic effects.

Consequences of public exposure to transuranium elements in the environment are extremely serious questions which should be addressed by the most knowledgeable and objective scientists in the field of radiation health effects. It is far from clear that the unidentified scientists who generated the proposed guidance have such credentials. The quality and content of the guidance report suggest otherwise.

Based on present state of knowledge of the genetic and somatic health effects of insoluble alpha emitting particles, public exposure to such particles must be restricted to the practical minimum--several times fallout or less."

Staff Response - Dr. Martell's conclusion that the proposed guidance is based on "hopelessly inadequate information" is somewhat overstated. The Agency uses dose models developed by an international commission of radiation protection experts. Similarly, analyses of radiogenic lung cancer developed by the National Academy of Sciences and derived from exposure of humans to radiation are used to estimate risk. The question is not whether the Agency's scientists are knowledgeable or objective, but whether they could responsibly disregard this information, developed by a large group of scientists, on the basis of the untested model of carcinogenesis proposed by the commentor.

Where possible, the guidance is based on epidemiological information on the hazard from alpha emitting radioelements. The risk estimates used are tempered with information from animal studies and from other human exposures. While there is uncertainty in the risk estimates, it is not orders of magnitude and probably is less than a factor of 5.

8. National Council on Radiation Protection

The factors for the uptake from the GI tract in Annex III are of considerable importance because they are orders of magnitude higher than have been used. However, there is practically no justification for them nor is the estimated degree of conservatism indicated.

Staff Response - The basis for the selection of these factors is given in Section 6 and in Technical Note CSD-78-1 (selected topics: Transuranium Elements in the General Environment, Office of Radiation Programs, EPA, 1978).

9. Colorado Environmental Health Association

As for the guidance itself, Johnson (1977) in a paper presented to the Annual American Public Health Association has reported increased leukemia death rates in the eight census tracts nearest Rocky Flats as compared to nineteen census tracts located in southern Jefferson County. These death rates range from 2 to 3 times the rates from southern Jefferson County. The census tracts nearest Rocky Flats range from 3 to 33 mCi/km^2 or 0.003 to 0.033 uCi/m^2 in plutonium contamination of the soil. The proposed guideline of 0.2 uCi/m^2 is from 6 to 66 times the level associated with increased leukemia rates according to the study.

Staff Response - Dr. Johnson's 1977 report on a possible association between plutonium contamination and the annual rate of 4 leukemia deaths around Rocky Flats and 1 leukemia death in Golden County (as compared to 2 leukemia deaths in southern Jefferson County) is premature. As Dr. Johnson points out, local (cancer mortality) rates vary widely.

J. Sutherland (Director of the Cancer Patient Data System, Regional Cancer Center, Denver) pointed out in his June 2, 1978, memo to the Rocky Flats Monitoring Committee: "Because of the small numbers of cases involved, it is important that another control area be identified to compare to the Rocky Flats area. It would not be surprising to find a random fluctuation of 2 cases of leukemia in various areas of Colorado. For example, the number of thyroid cancer deaths in Colorado fluctuates from one to eight cases per year during the period 1960-1976 with no discernible trend. The eight cases in 1968 are much different than the two cases in 1969, but this difference is meaningless."

Sutherland also pointed out possible problems in accuracy of diagnosis available from death certificates, mobility of the population and the need for examining the incidence pattern over an extended time period. He concluded: "The results reported by Dr. Johnson are preliminary and of a suggestive nature only, and provide no conclusive evidence of anything due to small numbers of observed cases over a single year using death certificates. I feel that Dr. Johnson has stated this in his presentations, but perhaps not forcefully enough."

Indeed, Dr. S. W. Ferguson (Chief, Chronic Disease, Colorado Department of Health, Denver) pointed out in his February 23, 1978, letter to Dr. Carl Johnson (Director of the Jefferson County Health Department) that the Rocky Flats and control areas examined by Dr. Johnson each have a lower combined lung and leukemia incidence rate than was observed in two other control areas, one in Jefferson County and one in Arapahoe County. Dr. Ferguson also pointed out that population growth rates in the census tracts examined may play an important part in interpretation of the cancer rates.

Before an association of plutonium contamination and leukemia can be inferred, data must be available for a number of years to average out the normal large fluctuations in annual death rate seen in small populations. Duration and comparability of residence times in the area must be established, comparability of populations for occupational and environmental exposure to known carcinogens, current and prior exposure, age, and sex distribution, etc., must also be estimated. Dr. Johnson has yet to adjust for these variables.

10. Department of Defense

Basic Guidance: The proposed guidance of 1 mrad per year to the lung and 3 mrad per year to the bone are considered to be overly restrictive, possibly by a factor of 100. If this is true, screening levels and permissible annual dose rates should be increased accordingly. Explanations follow:

The Summary Report gives risk estimates derived from an EPA Life Table Methodology. An illustration of results using the EPA Methodology and NAS-BEIR data is given in Annex 4, pg. 9 of the Summary Report. Background radiation (100 mrem per yr) is indicated to cause 144 premature deaths per cohort-lifetime. (The single value is determined as an arithmetic mean of geometic mean relative risk and geometric mean absolute risk, where the geometric means are of two "plateau" values. This averaging method is presumably the one followed by EPA elsewhere in the Summary Report). Since lifetime is 71 years the EPA Methodology yields 2 deaths per cohort-year due to background radiation. The NAS-BEIR Report (pg. 169) yields 3614 "excess deaths" per US-Population-Year due to background radiation. (This value is determined also as the arithmetic mean of geometric means of data given at pg. 169). This value can be expressed in similar units to those used by EPA--assuming 200 million persons as US Population and 100 thousand persons in a cohort, the NAS-BEIR risk methodology gives 1.8 extra, premature deaths per cohort-year. Thus, the two risk methodologies yield equivalent results when evaluating background-radiation impact.

The NAS-BEIR Report shows (pg. 171) absolute risk of lung cancer as 1.3 per million-person-year-rem. (Similar values are given elsewhere in the Report; e.g., "best" risk estimates range from 0.07 to 1.6 on pg. 151, and the average for adults only is given as 1.0 on pg. 150. These estimates are primarily on case studies of persons chronically exposed to radiation). The NAS-BEIR input data is given in rad units, and conversion to rems is made in the Report by using an RBE of 10. Absolute risk of lung cancer according to NAS-BEIR then is 13 deaths per million-person-year-rad, or 0.013 per million-person-year-mrad.

The EPA Rationale for Guidance states "The risk at the proposed guidance level is estimated to less than one chance in a million per year...". As used in this instance, "less than one" means "in the order of one" since the value is obtained by dividing the risk per cohort-lifetime (10 deaths) by 71 years. Since the proposed lung guidance level is 1 mrad per year, the EPA Methodology gives a risk of 1.4 deaths per million-person-year-mrad, in contrast to 0.013 deaths per million-person-year-mrad estimates by NAS-BEIR Methodology.

Since the EPA and NAS-BEIR methodologies give equivalent results for estimates of background radiation effects, one would not expect estimates to differ by a factor of 100 for the case of lung radiation effects. The reason for this discrepancy is not apparent in the background material provided. Perhaps the real answer will be apparent when EPA "in-preparation publications" (References 1, 6 and 9, Annex III and 5, IV) are made available for review. If not, then EPA should provide an explanation for the apparent difference.

The Summary Report makes the case that a risk of "one in a million" is suitable for transuranics in the environment because it is comparable to risks used for other carcinogens. If the NAS-BEIR risk estimates are correct, the EPA estimates are in error and the risk of one-in-a-million is to be maintained, then the proposed guidance must be stated as 100 mrad per year to the pulmonary lung, not 1 mrad per year. Bone dose and screening levels also must be increased.

Staff Response - This comment is based on an erroneous interpretation of the information on absolute risk given on page 171 of the 1972 NAS-BEIR Report. The absolute risk for lung cancer is listed as "1.3/10^6/year/rem." This risk coefficient in the 1972 BEIR Report means that the probability that an individual will die of excess lung cancer following a one rem dose is 1.3×10^{-6} for each person year at risk. It is not the risk for a given dose rate (rem per year). This interpretation can be verified by calculating the absolute risks tabulated for total cancers on page 173.

Because an individual averages about 35 person years of risk for each annual dose increment received over a lifetime (lifetime plateau), the lifetime risk is about 35 times larger than assumed by the commentor. Moreover, averaging relative and absolute risks and considering the increased effect of childhood exposure increases the risk estimates by an additional factor of about 3. The neglect of these factors by Department of Defense has the overall effect of their underestimating the risk by a factor of more than one hundred.

11. Colorado Department of Health

The Department has been allowed to review and comment on several of the earlier drafts. Each time we have requested simplified equations to inform the reader as to the relationships between the risk, the biological risk estimator, the dose or dose rate commitment, the air concentration and the soil concentration. While the entire document does address these matters, nowhere is the relationhip summarized to place the entire process in prospective. Additionally, we have also commented that all of the equations be provided in detail. The "Plutonium Air Inhalation Dose (PAID)", Technical Note ORP/CSD-77-4, document was an attempt to provide the dose calculation procedures used by EPA in the development of the guidance. While our review of this publication is currently incomplete, there are some rather important defects involved. Figure 1, page 5, has improperly depicted pathways (d) and (g). Appendix I does not identify the terms used in the derived equations to allow another agency to use it with relative ease. The equations as provided are incomplete, as there are summations that must be done for each equation. Appropriate notation is necessary if the equations are to be correct. Appendix II does provide an example; however, the values used are not easily discernible. With the provision of the term identification in Appendix I and the values in Appendix II, calculation to confirm the EPA process would be properly provided for. It must be pointed out that the EPA and this Department's chronic exposure dose rate calculation procedures produce results not significantly different for the same parameters.

Staff Response - The misprint in Figure 1 of the PAID document was inserted when this figure was drawn. The equations and computer code are not affected by this error. The equations in the PAID Appendix I are complete in that they are valid for any organ or lung compartment in a chain. While they must be summed to obtain total dose/dose rate, the summation process is described in the main text. While the request for a simplified set of equations is understandable, it is not likely that any such set would cover the range of cases considered in the guidance document. The computer code is available on request from EPA.

12. Colorado Department of Health

Annex III of the guidance document provides data on various aerosol particle size distributions and resultant doses, etc. The ICRP in adopting the TGLM Clearance Model used only a 1 um AMAD aerosol particle size distribution. The pathway parameters recommended by the ICRP are based on that particle size for deposition in the various compartments of the respiratory tract and translocation to the blood and gastro-intestinal tract. The use of particle sizes considerably smaller than 1 um AMAD for Class Y compounds will result in an underestimate of the health risk due to the greater effective solubility of the smaller particles. The document references particle size distributions down to 0.01 um AMAD; however, the tables in Annex III do not include that particle size.

Staff Response - The question in not clear. While the ICRP recommended that, for unknown aerosol size distributions, a 1 um AMAD be used in the ICRP model, the ICRP Task Group Model is applicable to a wide range of particle size distributions (Figures 13 and 14 of Ref. 5). One limitation of the model is that solubility is a function of the compound class and is not related to particle size. The guidance document was based on particle sizes from 0.05 um to 5.0 um. Typical results for this range of sizes are given in Annex III. This size range encompasses most aerosol distributions (Ref. 5, p. 183). Aerosols consisting of smaller particles are outside the range of validity of the ICRP model (Ref. 5, p. 185) and, in any event, are expected to result in decreased, not increased, pulmonary deposition (Ref. 5, p. 185).

The question of increased solubility has been considered by EPA. Some typical results for Class W compounds are given in Section 6.

13. Conference of Radiation Control Program Directors

The method of calculating dose must be more explicit so that the entire procedure can be duplicated by those interested. It should also be pointed out in the document that fresh soil contamination may be a Class W compound which would provide a greater hazard to the bone. The basic guidance should be the primary controlling factor. In some circumstances reliance on the Class Y data and the associated soil screening value will not provide adequate protection.

Staff Response - The method used in calculating doses is relatively standard in that it follows the ICRP TGLD-lung model and, for the most part, uses ICRP metabolic parameters for the reference organs. Estimates of the hazard of Class W compounds can be found in Section 6.

The "soil screening" level is specifically designed to address only those cases where inhalation is the primary pathway to man. In most cases of environmental contamination, the suggested screening level of 0.2 uCi/m^2 leads to pulmonary lung and/or bone dose rates well below the Guidance recommendations. The lung dose rate is generally governing because newly deposited transuranium element contamination, which may consist of very fine particles, is relatively insoluble. The more weathered and soluble particles are expected to have a larger activity median aerodynamic diameter (AMAD). Section 6.3.2 in this volume describes the application of the proposed guidance to Class W transuranium compounds. In a few cases where alternative pathways, such as ingestion, comprise a significant part of the total exposure, these must be considered on a site-specific basis.

14. National Resource Defense Council

EPA underestimated the somatic and genetic effects of low dose/low dose rate irradiation.

Staff Response - Somatic Effects - The Agency notes that risk to health due to transuranium elements in the environment is almost entirely due to high LET (alpha particle) irradiation and that the Agency's risk estimates are based only on the potential effects of alpha irradiation. With the exception of Dr. K. Z. Morgan's paper, the references on somatic risk cited by the NRDC discuss the effects of low LET radiations. While the Agency agrees there is considerable controversy concerning the effects of low LET radiations, none of the new studies cited by the NRDC provide information on the risks due to chronic exposure from internally deposited alpha particle emitters. Dr. Morgan's discussion of the inhalation hazard due to plutonium is based on acute effects from massive doses, (kilorem) not cancer risk. The baboon studies he cited are not relevant at the low doses where delayed cancer, not acute health effects, are the potential public health problem.

The Agency agrees with the 1972 NAS-BEIR Committee that the linear hypothesis may either overestimate or underestimate the risks due to low levels of ionizing radiation (EPA-520/9-73-003-D). However, as stated in Annex III, the Agency believes appreciable departures from a linear response are less likely for high LET than low LET radiations. Nevertheless, the Agency recognizes that all current risk estimates are of necessity based on incomplete data. Because of the uncertainty in radiation risk estimates, the Agency contracted with the National Academy of Sciences in 1976 to constitute a new BEIR Committee to reevaluate the potential health risk due to both high LET and low LET radiations. This Committee is reviewing the most recent radiation health effects information, including that on alpha particles, in order to determine to what extent the 1972 NAS-BEIR Committee risk estimates used in the preparation of these Guides may be changed. The Agency will consider the need for modification of its risk assessment upon completion of the NAS study in 1978.

Staff Response continued - Genetic effects - The NRDC cites two studies to support its view that the estimate of genetic risk is too low. The first by Dr. M. F. Lyon calls attention to a possible increase in genetic risk at very low-dose rates over that calculated by the BEIR Committee in 1972. The EPA risk estimates are for alpha particle emitters and therefore do not assume fewer effects at low-dose rates. As explained in Annex III, the Agency's estimates of the genetic risk is five times greater than that of the 1972 BEIR Committee. The other study cited by the NRDC is the report by B. K. Trimble and J. H. Doughty on the frequency of genetic disorders found in British Columbia. The reported frequency in British Columbia of disorders having a complex etiology, which includes a genetic component, is a factor of two greater than that listed in the 1972 NAS-BEIR report; 90 per 1000 live births as compared to 45 per 1000. The important question however is the degree to which these diseases have a mutational component, i.e., are transmitted to future generations. The 1972 NAS-BEIR Committee estimates their mutational component as between 5 and 50 percent and the Agency's genetic risk estimates in Annex III are based on this range of possible values. Recently, (1977) UNSCEAR has estimated ten percent as an upper limit for this mutational component. Therefore, the Agency believes its estimate of genetic risks is conservative and that the range of genetic risks presented in Annex III encompasses the factor of two reported in British Columbia study. The Agency notes that until his recent death, Dr. Trimble was a member of the NAS-BEIR Committee reevaluating their 1972 report and that his studies will be considered in preparing the Academy's new estimates of genetic risk to be published this year.

15. Natural Resources Defense Council

By using an incorrect relative damage factor for bone, EPA underestimated the radiotoxicity of plutonium in bone.

Staff Response - The relative damage factor "n" had been used by ICRP Committee 2 to relate the risk of bone cancer due from radium-226 uniformly deposited in bone to the dose and risk from plutonium and other radionuclides which deposite on bone surface and thereby irradiated a larger proportion of cells at risk for cancer induction. Since in both cases the dose was calculated by averaging the emitted energy throughout the skeletal mass, the n factor corrected for the uneven deposition of energy by bone surface seekers. It should be noted that the ICRP has recently (1977) defined dose-to-bone in terms of the dose-to-bone surfaces and defined a quantity N "the product of all other modifying factors", (except the quality factor, Q) as unity. In view of the context of the NRDC comment, it is assumed here that the NRDC comments refer to n, "the relative damage factor for bone", and not the quantity N.

In its review of the data of radiogenesis of bone cancer, the Agency carefully considered the precedents established by the ICRP, K. Z. Morgan, and others in relating estimates of risk due to radium-226 to other alpha emitters. However, the Agency staff concluded that such an approach was too indirect because of the dosimetric difference between the results of radium-226 and plutonium deposition and, instead, used a more direct approach based on epidemiological studies of persons chronically irradiated with radium-224 which, as explained in Annex III, irradiates only bone surfaces. These data were not available when the n factor concept was developed by the ICRP. Contrary to the NRDC comment, no N or n factor has been implied by the Agency in its evaluation of the risk of radiogenic bone cancer. Rather, the risk estimate is the result of a straightforward application of the most relevant biological data on the results of human exposures.

16. Natural Resources Defense Council

EPA did not consider the harzard of hot particles in the induction of lung cancer.

Staff Response- The Agency agrees with the National Academy of Sciences' study that concluded that, if there is a hot particle risk, it is small by comparison with lung cancer risk attributable to the generalized alpha radiation (NAS-76). As pointed out in Annex III, the Agency's estimates of the risk of lung cancer are conservative in that it is based on the dose to that portion of the Agency receiving the highest average dose, the pulmonary region, notwithstanding the fact that most radiogenic lung cancers in humans are found in the bronchial region where the dose at the proposed limits is a factor of more than ten smaller, Table 3-2, Annex III. The Agency's position on the hot particle hypothesis and the NRDC petition to use this hypothesis as the basis for Agency estimate of risk due to the inhalation of plutonium was published in 1977, 42 FR 1288. While the Agency has been aware of the NRDC's dissatisfaction with the National Academy's analysis of the hot particle hypothesis, it does not believe that a recapitulation of this issue is necessary to insure that the estimates of lung cancer risk used in the preparation of these Guides are adequately conservative.

17. Nuclear Safety Associates

In a technical point, the dose-risk relation for inhaled transuranics was based on the product of an annual average dose rate to pulmonary lung tissue of one millirad per year and the unit risk appropriate for bronchial cancers (i.e., in bronchial tissue). The dose and the risk estimates were not to the same tissue. The dose to pulmonary tissue was calculated by the EPA to be about 20 times higher than the tracheobronchial dose. However, in Hiroshima survivors, the significant increases in lung cancer occurred in the bronchi rather than in the pulmonary region. In short, a lung dose rate limit based on the product of the region receiving the highest dose and the risk to a different region which has the highest risk per unit dose would not be realistic and would not provide protection corresponding to the intended maximium level of risk. Instead, a lung dose rate limit set on this basis would appear to be much more restrictive than intended.

Staff Response - This information was included in Annex III and the point made is recognized by the Agency. See the reply to comment 16.

18. Jefferson County Health Department

...I believe that the estimated risk is understated...much more than a "small fraction" of plutonium retained in the lung is translocated to the bone. (The Guide should be reduced because of the factor of 3 uncertainty in Annex III). (Page 60948 - F.R.)

Staff Response - The Agency agrees that characterizing this fraction as small is incorrect. In accordance with the ICRP task group lung model, the risk estimates in Annex III are based on the assumption that about 20 percent of the material initially deposited in the lung is translocated to other organs. However, the Agency does not agree that the degree of uncertainty in the estimated risks are a reasonable basis for reducing the proposed Guides since the degree of uncertainty in the risk estimates, as well as the conservative nature of the exposure situations, (e.g., lifetime residency, and the conservatism in the risk modeling) were considered in the development of these Guides.

19. Jefferson County Health Department

The dose limits are higher than those promulgated by EPA for drinking water.

Staff Response - The comment seems to imply that the maximum contaminant limits for radioactivity in drinking water replace Federal Radiation Protection Guides for exposures to the general population. They do not; the drinking water regulations are specific on this point (41 FR 28409). The drinking water limits are for a single pathway, finished drinking water. The proposed Guides for transuranium elements in the environment include the doses due to inhalation and food pathways and are limited to contamination by transuranium elements.

The proposed guides provide for a 3 mrad annual dose limit for bone tissue after lifetime exposure. The drinking water regulations limit the annual dose rate to bone tissue due to alpha particles from radium-226 to 15 mrad per year (EPA-570/9-76-003, National Interim Primary Drinking Water Regulations).

20. Jefferson County Health Department

In addition to resuspension of plutonium from surface dust, we must also consider the release of particulate to plutonium from plutonium-processing plants. These particles are for the most less than five microns (micrometers) in size and large numbers are released at times. Eight days after a fire at Rocky Flats in 1957, as many as 125 million of such five micron particles of their equivalent were released in a single day from a stack (3). A two micron particle of plutonium oxide, if inhaled, would produce a dosage of over two millirem to the lung, 96 millirem to the tracheobronchial lymph nodes, and six millirem to bone (4). A particle five microns in size could be inhaled and retained and produce a dose to about 40 millirem to the lung, 1,700 millirem to the tracheobronchial lymph nodes, over 130 millirem to the bone, 50 millirem to the liver, eight millirem to the kidney, and two millirem to the gonads, where a pattern of microdeposition of plutonium would give a proportionately greater effect than would be expected. Particles of this size, of course, are microscopic in size and of the same order of size as bacteria, and may be blown by the wind for great distances. A single particle only two microns in size, if inhaled and retained, will produce a dosage exceeding the EPA 4 millirem maximum annual dose (4).

Staff Response - The Guidance does not apply to routine, controlled emissions. The dose estimates used by Dr. Johnson are taken from a 1974 paper by Dr. N. Barr. Dr. Barr presented his estimates for 0.3 um AMAD (0.1 um Diameter) particles as either Class Y or Class W compounds. Dr. Johnson has combined the estimates for

Class Y and Class W, an impermissible aggregation, and then used these dose estimates for a 5 um (actual diameter) particle. Thus, his soluble/insoluble particles overestimate dose by a factor of about 4 due to change in particle diameter. Moreover, in his analysis they are assumed to continue to irradiate lung and lymph nodes even after they dissolve and are deposited in the rest of the body. The reference to the 4 mrem maximum contaminant limit for drinking water is inappropriate. See response to comment 19.

21. Jefferson County Health Department

The proposed guidelines state that persons with a continuous exposure to one millirad of plutonium-239 would have less than one chance per million per year and less than 100 chances per million in a lifetime of dying of cancer. One millirad of plutonium-239 is equivalent of 20 millirem in lung, with correspondingly larger values in other organs. I estimate that there will be a total increase of all cancers of perhaps 0.06 to 0.2% over a period of seventy years due to this exposure, or 600 to 2,000 excess deaths from cancer per million persons (4). In addition, there will be an increase in the incidence of all genetic dieases by 0.1%, and ill health related to chromosome mutation by 0.6% for all succeeding generations. I think that in making such estimates that it is risky to rule out potentiating factors such as the effect of smoking on asbestos workers and uranium miners. Such potentiating effects may be expected.

Staff Response - The author of the comment appears to have misinterpreted the 1972 NAS-BEIR Report. The BEIR Report increase in cancer was calculated on the basis of chronic-uniform total body irradiation and reflected an increased incidence in cancer mortality, not an increased incidence of mortality due to all causes. A 1% increase in cancer mortality is about a 0.2% increase in mortality from all causes. Therefore, the commentor's results are five times greater than a correct evaluation.

In addition, developing risk estimates for individual organs requires development of risk estimates similar to those in BEIR Tables 3-3 and 3-4 for each organ. The BEIR Report risk estimates for total body dose cannot be applied. Moreover, even if such an approach were taken, the risk estimates would be too high by a factor of 2 or more since the dose to lung is equilibrium before other organ doses for Class Y compounds. This factor was neglected also.

In either case his calculation of mortality is wrong. The increase in the BEIR Report is given as a percent increase in cancer mortality, not total mortality. Assuming an increase of 0.06% to 0.2% in the total cancer mortality, yields, per million persons at risk, an additional 108 to 360 cancer deaths, not the 600 to 2000 calculated by

Dr. Johnson. Further adjustments for differences in dose rates and total doses for specific organs would yield estimated excess cancer mortality close to that developed by the Agency in Appendix III of the proposed guides.

A similar situation holds for Johnson's estimates of genetic risk. If the BEIR Report genetic risk estimates are used, the 0.1% increase in incidence of genetic diseases and 0.6% in ill health calculated by Dr. Johnson imply each parent received an average of one rem gonadal dose between birth and age 30. The gonadal dose estimated by Dr. Johnson appears to be 2 thousandths of a rem or less per person. The genetic risk, thus, appears to be overstated by a factor of 500 or more.

The commentor's final comment, that potentiators such as smoking should not be discounted, is valid. Since lung risk estimates are derived primarily from uranium miners studies and the uranium miners smoke about as much as U.S. males of the same age, the synergism of smoking is already included in the risk estimate. The effects of any unidentified potentiators are also included in the risk estimates to the extent that the exposure of uranium miners is equivalent to that of the U.S. population. In the absence of any other data no further adjustment of risk estimates can be made.

22. Jefferson County Health Department

In any discussion of dose limits for plutonium or other transuranium elements, new evidence relative to the adequacy of such dose limits must be considered. A recent report of a study of plutonium workers at Rocky Flats found a significant increase in chromsome abnormalities in the blood lymphocytes of plutonium workers who had received only 1% to 10% of the body burden of plutonium permitted by the present federal guidelines (5). This is very significant, because it indicates that the present guidelines are inadequate and are not providing protection for plutonium workers. Existing federal guidelines to provide radiation protection from plutonium should be decreased by at least a factor of 100 in order to achieve a level where no observable effects are noted. A reduction in the maximum permissible level of plutonium for workers should result in a corresponding reduction in the radiation protection guides for the general public. Recent reports by Dr. Karl Morgan and Dr. Myers also suggest that the present Federal guidelines are too high by a factor of about 200 or more (6,7).

Staff Response - The Agency is familiar with Dr. Brandom's work on peripheral lymphocyte cytogenetics, and at present agrees with Dr. Brandom's position of not drawing any hereditary or clinical implications from the data. Chromosome aberrations have been observed after many types of physical or chemical insults, but as yet, there is no interpretation of the significance of persistant aberrations in peripheral lymphocytes. Currently, identifiable clinical conditions have not been correlated with a slight increase in aberrations. However this topic is worthy of further investigation, the results of which will, as necessary, be incorporated into Federal guidance.

However, it should be noted that the lowest bone marrow doses to which these industrial workers are being exposed and where these effects are seen is about 50 times greater than would occur at the proposed guides.

The Agency has also considered and previously commented on Dr. Morgan's report, (W. H. Ellett, *et al.*, pp. 587-601 in *Transuranium Nuclides in the Environment*, IAEA, 1976). Dr. Morgan used a round-off of his estimates which increased the numerical value and also used some acute injury data which was not appropriate to the question. When properly compared, as done in the referenced paper, the Agency's bone risk estimate differed from Dr. Morgan's estimate by a factor of 3 or less.

23. Jefferson County Health Department.

The report notes that "unlike radium-226, which is distributed throughout the bone volume following long-term ingestion, plutonium is preferentially deposited and retained near bone surfaces". As much as 30% to 50% of plutonium has been shown to be retained on osteogenic cells. Americium and curium are also retained on bone surfaces, and so, more prone to be a cause of radiogenic bone carcinomas than is radium.

Staff Response - In assessing the bone cancer risk, the Agency assumed that plutonium, americium and curium are retained on bone surfaces, and the risks have been calculated accordingly.

24. Department of Energy

As a general comment, the EPA could have more justifiably employed generally accepted dosimetric and risk estimation techniques and parameters, such as those recommended by ICRP, NCRP, and in the BEIR and UNSCEAR Reports. Where changes from these established procedures seemed essential, because of important new information, these changes should have been clearly justified. This was not done. In fact, it is impossible to check any of the detailed models employed or calculations made in arriving at the numerical values tabulated in Annex III and Annex IV. These are referenced to unpublished EPA documents, and were calculated by a computer code that is similarly undocumented.

With the above very serious reservation, it must be acknowledged that the numerical conclusions relative to dosimetry and associated risk appear to be not grossly unreasonable, though sometimes stated in a manner that exaggerates the confidence one is entitled to place in such numbers. A few of the more serious shortcomings of the Proposed Guidance, in this area, are discussed below.

Ingestion Route: Dose relationships involving transuranic concentrations in soil or air are developed only for the inhalation route. It is stated in many places that the inhalation route is most important, and implied that if it is controlled, one can ignore ingestion; however, in some other places it is stated that ingestion may need to be considered. The conclusion that ingestion is relatively unimportant apparently arose from an unjustified assumption that environmental transuranics were always very insoluble, and from lack of adequate consideration of external transuranic contamination food. This conclusion was also supported by the use of a lung cancer risk factor larger than is customarily assumed and a bone cancer risk factor smaller than is customarily assumed. Although it does not appear likely that ingestion will be a more important route than inhalation for most exposed persons, it is not all unlikely that some "critical segment" may receive a larger dose from ingested transuranics than it receives from inhalation. It would seem incumbent upon the EPA to evaluate the total pathway from soil to cancer for the ingestion route, to the same degree that this has been done for the inhalation route. The dosimetric behavior of such Class W materials should be given consideration in this Guidance. Presently, this consideration consists only of a reference to an unpublished report. Appropriate consideration Class W compounds would increase the relative significance of bone and liver cancers and genetic effects, at the expense of lung cancers.

Gonad Dosimetry: The treatment of gonad dosimetry and risk is considered to be inadequate. The exact parameters employed for dosimetric calculations are not defined in the Proposed Guidance, but it is implied that the dose is taken to be half that calculated for bone. This assumption seems to result from using the estimated average dose to ovaries, and 2 to 3 times the estimated average dose to testes. The increase weighting of the testes dose is justified by autoradiographic studies in mice that showed preferential deposition of plutonium near spermatogonial stem cells. Recent studies indicate, however, that differences in testes anatomy between mouse and man make it unlikely that the same kind of non-uniform deposition observed in the mouse would affect the dose to spermatogonial stem cells in man, DOE Doc. LF-56, pp. 389-403 (1976). There is also evidence that irradiation of the mouse ovary is virtually without effect. It would therefore appear that the estimates of genetic effect in the proposed Guidance are too high by a factor of about five.

Cancer Risk Estimates: Because of unavailable references, it is impossible to reconstruct the total basis on which risk estimates were derived. The estimate of bone cancer risk was quite straightforwardly based on the human ^{224}Ra data, and though one may quibble with the validity of small corrections applied to the original observations of Spiess and Mays, the number arrived at is probably better, for transuranics, than the considerably higher estimates of the BEIR Report and ICRP Publication 26. It is not at all clear how the lung cancer risk was derived. The result, however, reflects a greater risk than has usually been assumed for lung irradiation. This combination of a higher than usually assumed factor for lung cancer, and a lower than usually assumed factor for bone cancer, results in the prediction of an unexpectedly high ratio of lung to bone cancers. This may be as good as any other estimate, but, because it is different, requires justification that is not given in the Proposed Guidance.

Uncertainty of Risk Estimates: The general tone of Appendix III implies a certainty with regard to risk estimates which is unjustified and could be seriously misleading to responsible officials and to the general reader, unaware of the uncertainty of many of the assumptions employed. This Annex ignores express warnings of BEIR Committee and NCRP, concerning the need to qualify such estimates with a clear statement of inherent uncertainties. The BEIR Report states that"...explicit explanation and qualification of the assumptions and procedures involved in such risk estimates are called for to prevent their acceptance as scientific dogma". The Proposed Guidance states on p-3 of Annex III, "that for highly ionizing radiation such as alpha particles from plutonium the linear non-threshold hypothesis is unlikely to overestimate the actual risks" (emphasis supplied). The highest and lowest of BEIR estimates are presented as a "range" implying that the real number will fall somewhere between these numbers. Derived risk estimates are often given to 3 significant figures. It would seem very important in a document such as this, that affected agencies and the public not be mislead. This is not a question of conservatism or lack of conservatism. The risks from exposure to very low levels of radiation are simply not understood with the precision implied by many statements in this Proposed Guidance.

These general comments are abridged below in the staff response.

Staff Response - "EPA could have employed generally accepted dose and risk estimation techniques and parameters."

The basis for this comment is not clear. ICRP Task Group and Committee II dosimetry models were used throughout Annex III. The essentials of the life table risk analysis used by the 1972 NAS-BEIR Committee and in Annex III and IV are laid out on pages 171-173 of the 1972 NAS-BEIR Report. Estimates of the lung cancer risk are taken directly from the 1972 NAS-BEIR Reports and the 1976 NAS Report "Health Effects of Alpha-emmitting Particles in the Respiratory Tract." Because the Agency's assessment of bone and liver cancer risk are not found in the 1972 NAS-BEIR Report (where liver cancer was not considered and the effects of bone surface seekers given insufficient consideration) the Agency prepared its own risk estimates for these cancers following the methodology described in the 1972 NAS-BEIR Report. Over six pages in Annex III were used to document the information used to develop the risk estimates for liver and bone cancer. The Agency has acknowledged in Annex III that the National Academy of Sciences' ongoing review of radiation health effects information will provide a more current compilation of the risk due to irradiation than was available at the time the proposed guidance was prepared. When the new BEIR Report is completed, the Agency will review the risk estimates in the proposed guides to determine if significant changes are needed.

Dose relationships applicable to the ingestion of transuranics are described in Section 3.4.4., pp. 10-21 of Annex III. Table A 3-6 gives the dose to various organs due to the ingestion of four transuranics and Table A 3-7 for six. Table A 3-8 gives gonadal doses due to ingestion for six transuranics and Table A 3-9 lists dose due to chronic ingestion by infants.

No basis for the DOE assertion that "Transuranics other than plutonium are now considered to behave as Class W materials" is available. While it has been rumored that the ICRP is considering the classification of some transuranics in the W category, it has been the Agency's experience that ICRP's published reports can differ significantly from hearsay about their contents. Obviously Federal Guidance should not be based on hearsay. The dose and risk for Class W compounds are discussed in Section 6 where it is shown that the risk due to the inhalation of Class W compounds at the proposed dose rate limit is comparable to that for Class Y compounds.

25. **Department of Energy**

Since there have been many recent and extensive published reviews and collections of information on the biological properties and effects of the transuranium elements, it seems unncessary to provide a single reference to an unpublished document. (p-1, lines 13-15)

Staff Response - The document referred to contains 30 pages and cites over sixty publications in the sections providing information on biological properties and effects. Publication of this material separately was the result of an editorial decision favoring a shorter Guidance document. Xerox reproductions of this material were provided to the commentors in 1977.

26. **Department of Energy**

The implication that we know little about transuranics in gonads is misleading. The fraction deposited in gonads is somewhat uncertain only because it is so small as to be difficult to measure in the general population. (p-1, line 9)

Staff Response - The available data is neither extensive nor persuasive. Animal data shows such a wide range of inter-species variability that its application to man is tenuous. Variability in the human data is in part due to measurement difficulties. Moreover, there is no data on distribution patterns in human gonads and very sparce data for animals. These data are reviewed in the guidance document.

27. **Department of Defense**

The literature abounds with information on the biological properties of transuranium elements; therefore, why reference an unpublished review? Is it because it is an in-house pub? (p-1, p-2)

Staff Response - See response to comment 25.

28. **Department of Energy**

The statement in Annex III that refers to the "procedure used by the BEIR Committee in arriving at its best estimate of radiation risk". To refer to anything from the BEIR Report as a "best estimate"

seems contrary to the spirit of that report, which was, in most instances, careful to qualify its estimates as "fraught with uncertainty". Only in their Summary and Recommendations did they quote a "most likely" estimate, which is a statistical "most likely", assuming the accuracy of their models (an assumption they were elsewhere careful to avoid).
(p-2, lines 19-22)

Staff Response - The phrase "most likely estimate" not "best estimate" is correct. It appears in at least four places in the 1972 BEIR Report, (pages 90, 91, and 168) where it is used in the sense outlined in the comment, and also in the "Summary and Recommendations", (page 2). In the latter case it means the Committee's "best" guess given the range of values that can be estimated using the various models and risk coefficients given in the report. It is clear that the Committee did not believe their "most likely" estimate was very accurate, nor does the Agency believe so. Rather, the point of the cited sentence was to indicate that the method of averaging used by the Agency results in numerical agreement with those labeled as "most likely" by the Committee.

29. **Department of Defense**

The BEIR Committee Report takes great care in explaining what their "best estimates" mean. This document should at least acknowledge that there are qualifications surrounding the estimates and not present it as scientific fact. (p-1, p-2)

Staff Response - See response to comment 28.

30. **Department of Energy**

It is not clear what is referred to by the phrase "risk estimates listed below". (p-3, Line 6)

Staff Response - The phrase refers to risk estimates in Annex III.

31. **Department of Defense**

What risk estimates below? Those being derived by EPA, those taken from elsewhere or what? Also, is any model "appropriate"? (p-3, line-4)

Staff Response - See response to comment 32.

32. Department of Energy

The phase, "which of these models is appropriate", implies that one of them is appropriate, which does not necessarily follow. (p-3, line 7)

Staff Response - The Agency disagrees. There is a growing body of evidence that the absolute risk model is applicable to radiation-induced leukemia (and perhaps bone cancer) while models which incorporate the increased risk of cancer with advancing age are a better choice for such common cancers as breast and lung cancer. Ref: The Latent Period of Radiogenic Cancers Occurring Among Japanese A-Bomb Survivors. C. E. Land and J. E. Norman, IAEA Late Effects Symposium, March 13, 1977, Vienna.

33. Department of Energy

If, as the agency recognizes in the latter part of this sentence, the risks are based upon a hypothesis, by definition the risks are hypothetical.

The statement "that linear non-threshold hypothesis is unlikely to overestimate the actual risks", implies a certainty with regard to risk estimates that was not shared by the authors of the BEIR Report, who cautioned that "the foregoing estimates of mortality from radiation exposure may be too high, or too low, for a variety of reasons". (p-3, lines 14-17)

35. Department of Defense

This entire paragraph is a distortion. Contrary to the statement that "the agency dose not consider the risks due to ionizing radiation hypothetical...", the fact remains that they are hypothetical as estimated by the Agency. (p-3, line 2)

Staff Response - Due to our unfortunate wording, the comment fails to differentiate between two separate points in a single sentence: 1) an existence hypothesis and 2) the hypothetical shape of the dose response curve. These points are logically independent of each other. The Agency agrees with the BEIR Committee that current radiation risk estimates are uncertain and may be high or low. The statement which referred specifically to high LET radiation points out that for such radiation the BEIR estimates enjoy a higher degree of confidence since repair processes are unlikely to ameliorate the radiation effects.

35. Department of Energy

The reasoning of this paragraph is difficult to follow. It seems to be justifying an increased dose to children on the basis of an insignificant change in lifetime risk, but neither the increased dose to the child, nor the effect on lifetime risk, is adequately defined. Since the basic Guidance is terms of dose per year, not risk, the risk argument is technically irrelevant. (p-4, line 17 to p-5, line-3)

Staff Response - Section 1, pages 17, 23 and particularly the footnote on page 24 indicate clearly that this numerical Guidance applies to adult organ doses. No attempt is made in the Guides to justify the risk to children. Rather, the increased dose and risk to children has been considered in the estimates of the risk due to lifetime exposure. The pulmonary dose to children is about one and a half times greater than that to adults. This may increase the lifetime risk by about ten percent.

36. Department of Energy

The "logarithmic averaging" requires further description and justification. To imply that other conservative assumptions will balance a nonconservative bias, without identifying or quantifying these assumptions, confuses the analysis. (p. 5, lines 17-22).

Staff Response - The Agency does not endorse the exclusive use of either the largest or smallest risk values that can be generated with the BEIR risk models. The Agency's use of logarithemic averaging of the various 1972 BEIR risk estimates yields numerical results that agree with the BEIR Committee's "most likely" estimates. However, as stated in the Guidance document such a procedure weighs absolute risk estimates somewhat more heavily than the relative risk estimates. The degree of bias this introduces is small compared to the uncertainties in the risk estimates, e.g., for the case of lung cancer mortality, about ten percent. No attempt was made to offset indeterminate quantities.

37. Jefferson County Health Department

The dose and risk to health due to inhalation and ingestion of transuranium nuclides. On page 4 there is an inadequate explanation for the choice of the term "rad" in place of the more commonly used "rem". In a few years the dosage from gamma radiation from americium can be significant harzard in areas contaminated with transuranium element. There is adequate justification to use the more conventional term, "rem" in order to reduce radiation effects to a common denominator. Consequently, I recommend that the terms rad or millirad be converted to rem and millirem throughout this document.

Staff Response - The rem is not an appropriate unit for risk analyses since RBE and quality factors differ for various biological end points, see response to comment 92.

38. Jefferson County Health Department

In the last paragraph on page 4, the report states, "this provides a conservative estimate of childhood dose since deposition and retention in the lung should be less for children due to their smaller lung area". This is probably not correct, because of the higher metabolic rate and the greater physical activity of children. In addition, children spend much more time outdoors and are breathing air more near the surface of the soil than are adults. On page 5 it is noted that the Agency has chosen a less conservative relative risk model for children rather than the more conservative model which assumes children are ten times more sensitive to radiation than are adults.

Staff Response - The Agency utilized data on age specific minute volume, airway dimensions, and lung surface area to calculate the maximum that pulmonary deposition as a function of age. Deposition peaks around age 10. At this peak period, deposition per unit area is about twice that in infants and adults. The Agency's use of this value is likely to be slightly conservative since this occurs for only a few years during which the body is growing rapidly. Moreover, the contribution to lung dose and body burden from material inhaled during this period would probably be reduced by faster clearance, (the distance material travels to be cleared is shorter). Unfortunately these facts were not clearly stated in the paragraph.

39. Department of Energy

The triple negative in this sentence makes it very confusing. (p-5, lines 20-22)

Staff Response - The sentence should read "It is unlikely that the true risks are underestimates."

40. Department of Energy

The reasons given for "expecting" that inhalation will be "the most important pathway" are vague and insufficient. The conclusion, itself, will be questioned by some. (p-6, lines 2-15)

Staff Response - The amount of food and water coming from contaminated land and ingested by those inhabiting this area could be highly variable and certainly circumstances could arise where the ingestion pathway is predominant, at least for a limited time. Nevertheless, breathing on the part of inhabitants is inevitable and contaminated air is not as readily replaced as food and drinking water.

41. Department of Defense

The reasons given do not support the conclusions stated. (p-6, para. 1)

Staff Response - See response to comment 40.

42. Department of Energy

These statements are correct only for a highly insoluble form of inhaled plutonium. Dose to liver and bone, relative to lung, and the temporal pattern of this dose, will vary widely depending on the nature of the inhaled material. The lack of consideration of anything other than very insoluble forms is a consistent weakness of this Annex. (p-7, lines 10-14)

Staff Response - The statement is true for Class Y compounds. Class W compounds are discussed in Section 6.

43. Department of Energy

Again, the emphasis is on "highly insoluble transuranics," with no mention of more soluble transuranics. In fact, $^{239}PuO_2$ is probably the only compound that would qualify as a "highly insoluble transuranic" in the context of this sentence, and even this may be questionable. (p-7, line 25 to p-8, line-3)

Staff Response - See response to comment 42.

44. Department of Defense

It is not clear that administrative controls have any relationship with chosing the specific model. It may be fortuitous. (p-7, line 16)

Staff Response - (The comment is unclear).

45. Jefferson County Health Department

In paragraph two on page seven, the report states "the uptake by plants is relatively small, and most animals, including humans, have a high discrimination factor against transfer of these elements into the body tissues". However, some plants, such as algae and seaweed, have the ability to concentrate plutonium, presumably in a form that can be assimilated by animals. Chelating agents present in soils over a period of time may make the plutonium oxide in soil available for uptake by both plant and animals to a greater extent. (P-7)

Staff Response - The increased availability of transuransics after a period of time is covered by the Agency's use of increased absorption by a factor of 5 to 50 for biologically incorporated elements as compared to elemental forms.

The Guidance is based on a dose limit (rather than a maximum permissible concentration) and is therefore independent of the form encountered which must be considered on a site specific basis.

46. Department of Energy

Should "reference 5" read "reference 4"? Fig. A 3-2 seems to be from (5), but Table A 3-1 is from (4), and they are not completely consistent, as noted later. (p-9, line-11)

Staff Response - Yes.

47. Department of Energy

Justification and/or references should be given for the contention that environmental plutonium and other transuranics "are likely to be in the oxide or hydroxide form." There is considerable recent evidence to the contrary, particularly for the transplutonium elements. This becomes important for estimating doses due to ingestion and for the determination of the ICRP lung dose. (p-9, lines 15-18)

Staff Response - See Section 3.2, Annex II, response to comment 2.

48. Department of Defense

What is evidence for saying environmental sources of plutonium are likely to be "in oxide or hydroxide form"? In general, all the material here and preceeding seems to be biased toward insoluble transuranics with little regard for soluble forms. (p-9, line 15)

Staff Response - See Section 3.2, Annex II, response to comment 2.

49. Department of Defense

Same comment applies here with regard to unavailability of reference as was pertinent for the reference on the PAID code. One must accept the dose estimates calculated by EPA. (p-9, line 22)

Staff Response - The PAID code has been documented and published as EPA document, Technical Note ORP/CSD-77-4. See also response to comment 52.

50. Jefferson County Health Department

On page nine, the report notes that insoluble actinides have an estimated biological half-life in pulmonary tissue of 500 days. Plutonium and the other actinides leave the lung by the transport of particulate materials into the lymphatic system to the lymph nodes, or by elevation up the tracheobronchial tree, or by dissolution into the blood stream. It must be noted that the particle size of the respirable fraction of these particles is in the same order as bacteria, which likewise are able to be transported about the body. The estimated biological half-life of plutonium in the liver is assumed to be 40 years and for bone, 100 years. (p-9)

Staff Response - Although both bacteria and respirable particles can be transported to various body organs via blood, direct comparison is inappropriate because of the higher density of plutonium and differences in physiological transport mechanisms.

51. Department of Energy

Again, "only retention in the pulmonary region" receives attention. The sentence is incorrect except perhaps, for highly insoluble $^{239}PuO_2$. (p-10, lines 3-5)

Staff Response - Perhaps the sentence is not clear. This paragraph is comparing the dose to various compartments within the lung, not the dose to the pulmonary lung relative to other organs. In this context, the statement applies equally well to the more soluble Class W compounds. The sentence would be more clear if written: "In assessing the lung dose and risk due to the inhalation of Class Y transuranium elements, only retention in the pulmonary region is of primary importance."

52. Department of Energy

The unavailability of the PAID code precludes any possibility of checking dosimetric calculations. (p-10, lines 18-21)

Staff Response - The PAID code was made available to DOE reviewers in January of 1978. Published references cited in the text Annex, (7,8), contain essentially the same derivations as those given in the PAID documentation. The extension of these derivations to include the dose due to the daughter products of initially deposited parent radionuclides is straightforward.

53. Jefferson County Health Department

The last paragraph on page ten notes that the ICRP model is based on ambiguous equations, but in turn is used to calculate the annual dose rates resulting from inhalation of isotopes of plutonium, americium and curium for a number of particle sizes. This ambiguity is important to note, since such calculated doses are often presented with an air of unwarranted precision. (P-10)

Staff Response - The statement was apparently misread. The ICRP Report does not provide unambiguous equations. The PAID code for calculating doses and dose rates does use documented equations and a well-defined model based on the ICRP Task Group Report (Reference 5, Annex III). However, the reference to "unwarranted precision" is appropriate in view of possible differences between actual exposures and the results predicted by the task group lung model.

54. Jefferson County Health Department

On page eleven, the last paragraph, the report states that the high dose rate to the tracheobronchial lymph nodes is "not believed to be an important consideration in estimating risk" because of animal studies. I would question this assumption, in view of the length of life of man in relation to the length of the animal study periods. (P-11)

Staff Response - Although only the statement that "the lifespan animal studies showing that the frequency of respiratory lymph node cancer is negligible compared to other cancers caused by transuranics" was referenced in the ORP support document, there is also human data. Respiratory lymph node cancers have not been reported in uranium or other miners who have deposited inhaled uranium ore dust. Neither has lymph node cancer been associated with Thorotrast exposure even though Thorotrast does deposit in lymph nodes. There is no evidence reported of risk related to deposition of radioactive material in lymph nodes at this time in either man or animals.

55. Department of Energy

The section heading refers to the dose to the total body, but there is nothing in the section about total body dose. (p-12, line-1)

Staff Response - Total body doses are discussed only for the case of ingestion (Table 6-6) and should have been omitted from the heading referred to.

56. Department of Energy

A reference should be given for the statement that half life for transuranics in gonads may be longer than 100 years. It might be better simply to state that the amount present is too small to study the rate of release. (p-12, line-10)

Staff Response - Fish, et al., B. R. Fish, G. W. Keilholtz, W. S. Synder and S. D. Swisher, Calculation of Dose Due to Accidentally Released Plutonium from an LMFBR, ORNL-NSIC-74, USAEC, Oak Ridge, 1972 reference an estimate of infinite retention in gonads. They do not mention that the amount is too small to study.

Moreover, studies by D. M. Taylor reported in "The Uptake, Retention and Distribution of Plutonium-239 in Rat Gonads", Health Physics 32:29-31 (1977) indicate a variety of transuranics show no appreciable loss from the gonads. Again no problems in measurement were noted.

57. Department of Energy

Again, the Class Y assumption is unjustified for americium and curium. Why is ^{239}Pu specified as the oxide, while other compound forms are unspecified? (p-12, lines 18-21)

These calculations apparently assume (one cannot be sure without Ref. 6) a constant concentration of transuranics in air over the 70 years of exposure. This does not appear appropriate, particularly for the shorter-lived transuranics, since the concern is for single event contamination of soil.

Staff Response - All actinides (including americium and curium) are currently classified by ICRP as Class Y if in the oxide or dioxide form.

The chemical form is specified for Pu-239 oxide because a portion of the dose to liver and bone due to inhalation depends on the transgut transfer of material swallowed after the inhaled material is transported up the bronchial tree. For the Pu-239 calculation, the gut transfer for the oxide forms (0.0001) was used since it is the case most likely to be encountered in the general environment. Doses for americium, curium and high specific activity plutonium oxides were calculated for a gut transfer of 0.001 as in Table A 3-5 of Annex III.

The assumed duration of the chronic exposure is for a lifetime. Tables A 2-3 and A 3-3 are clearly labeled "Duration of Exposure" and go up to 70 years. It is likely but not inevitable that the concentration of shorter lived transuranics in air will vary with the half life of the radionuclide since the long term resuspension rate is likely to be constant. The Agency agrees that in many cases radioactive decay will reduce exposures from the shorter half life transuranics.

Table A 3-4 gives concentrations based on a constant annual intake. However, Table A 3-4 is not the Guide and need not be used where it can be shown, on a site specific basis, that the pulmonary dose rate of 1 mrad per year is not exceeded.

58. Department of Energy

The statement probably is not true. Much of the liver deposit may derive from particulate material transferred via lymphatics. (p-12, line-25 to p-13, line 3)

Staff Response - The sentence is not well worded. A better sentence would be: "Almost all of the dose to liver and bone is from material in the lungs and lymph nodes that has been transported via the blood to the bone and liver."

Phenomena of pinocytosis and macrophage transport are mentioned in a section on "The Physiological Basis of Transuranic Element Dose Estimates" in Annex III, Reference (1), but the extent of their contribution to transport of nuclides in the body is not known.

See J. A. Schallberger, M. W. Dewhirst and J. L. Lebel "Lymph Transport of Soluble and Insoluble Plutonium" pp. 19-27 in Radiation and the Lymphatic System, ERDA Symposium Series 37, 1976, for additional information.

59. Department of Energy

"0.09%" should be "0.009%" (p-14, line-22)

Staff Response - 0.09% is a misprint; 0.009% was used in the calculations.

60. Department of Energy

Although discussed, the concentration of transuranics in gonads, necessarily assumed by EPA for dose calculations, is nowhere stated. (p-14, line-20 to p-15, line-8)

Staff Response - It was assumed in Annex III that 0.0045% per gram of the transuranic material in the blood is concentrated in gonadal tissue for both females and males. Since the concentration in bone is 0.009%, the gonad dose rate is half that of bone tissue.

61. Department of Defense

The ICRP model uses 0.009%, not 0.09 (p-14, line-22)

Staff Response - See response to comment 59.

62. Department of Energy

Because of differences in testes anatomy between mouse and man, it seems unlikely that the same kind of non-uniform deposition observed in the mouse would have any effect on the dose to spermatogonial stem cells in man. (See A. L. Brooks, J. H. Diel and R. O. McClellan, LF-56, 399-403 (1976)). (p-15, lines 1-4)

Staff Response - The question of anatomy of the testes is not of prime interest in determining the dose to spermatogonia. What is important is the micro-distribution of plutonium and other transuranic elements. Distribution of plutonium differs between rat, mouse, and hamster testes, as discussed in Annex 3. Green, *et al.*, Nature 225:77 (1975) stated that plutonium appears to be deposited in intertubular spaces (∿47%) and in peritubular tissue (∿42%). Data on man and other species is needed to resolve the question. The dosimetry of plutonium in gonads is discussed in reply to comment 24 and also in "Selected Topics: Transuranium Elements in the General Environment," Tech. Note CSD 78-1, referenced in Annex III.

63. Department of Energy

Parenthetical statement is no longer correct. A recent study in rats concludes that "the concentration of alpha tracks over the mature or developing follicles and corpora lutea was only 10% of the concentration over corresponding areas of stroma". (See D. M. Taylor, Health Phys. 33:29-31 (1977)). (p-15, lines 4-5)

Staff Response - A more exact quote from Dr. Taylor is: "Only very limited autoradiographic studies were carried out on ovarian tissue and these suggested that the concentration of alpha tracks over the mature or developing follicles and the corpora lutea was only about 10% of the concentration over corresponding areas of stroma. (D. M. Taylor, Health Physics 32:29-31 (1977)).

Data developed from high resolution autoradiography by N. D. Priest, Int. J. Radiat. Biol., 31:59-78 (1977) shows the answer is far from clear at this time. Data of Green, et al., Int. J. Appl. Rad. Isot., 28:497-501 (1977) shows there is redistribution in the ovary with increasing time after exposure. Obviously while some information has been available, further data on distribution of transuranics in the ovary should be obtained.

64. Department of Energy

Use of a 30-year dose in considerations of genetic risk is justifiable only on a population average basis. This Guidance is supposed to protect the "critical segment" of the population, which in this case might be the 70-year-old men still producing children. This, again, points out the lack of definition of this "critical" segment. (p-15, lines 14-16)

Staff Response - A critical receptor is not addressed in these risk estimates. All risk estimates both genetic and somatic are in terms of the number of health effects per 100,000 persons exposed. Consideration of a critical segment of the exposed population refers to the dose calculation, not the risk calculation. The critical segment of the exposed population is defined in the guides; see also response to comment 35. In passing, it might be noted that only about 3 in 1000 families with the head of the household over age 65 have children under 3 years of age. Thus, those age 70 males are not a problem. (Population Characteristics 1973, Department of Commerce Series P-20, #258, 1973)

65. Jefferson Health Department

On page fifteen the report states that for an equilibrium pulmonary dose rate of one millirad per year, the dose rates to genital tissue in the first 30 years of life is calculated to be 1.4 millirad. Does this estimation take into account the pattern of microdeposition of plutonium in the testes which would give a higher value in millirem than might be anticipated from the actual amount of plutonium present in the testes? (P-15)

Staff Response - Yes, the gonadal dose calculated for transuranics does take into consideration the nonuniform distribution of the isotope in gonadal tissues.

66. Department of Energy

The statement is incorrect. Many soluble compounds have been employed in studying absorption of transuranics from the gut. The most extensive studies employed nitrates. (p-16, lines 14-17)

Staff Response - The statement only compares laboratory prepared plutonium oxides to plutonium oxides found in the environment. It does not address transuranics in general.

67. Department of Energy

It is not clear why "conservative estimates...are required". There are risks of erring in either direction. (p-16, lines 17-19)

Staff Response - The risk of over estimating the dangers of plutonium were considered in the development of these guides.

68. Department of Energy

The choice of transfer coefficients is presented as an arbitrary decision with inadequate justification for the exact numbers chosen. It is not clear that the usual conservatism "applicable to public health problems" is justified by the very limited problem associated with transuranics in the environment. This does not seem to be a public health problem in the usual sense of the term. (p-16, line-19 to p-17, line-2)

Staff Response - The Agency's selection of gut transfer coefficients was largely based on the recommendation of Battelle-Northwest Laboratory scientists having, as a group, the most extensive experience in this field. See section 6.

69. Department of Energy

Sentence is correct only if ^{239}Pu and ^{240}Pu are excluded. Absorption of these isotopes, assumed to be oxides, is increased 50-fold by biological binding, according to Table A 3-5; 10% biologically incorporated would result in 590% increased absorption of ^{239}Pu,^{240}Pu. (p-18, lines 5-6)

Staff Response - The dose caused by the biological incorporation of ^{239}Pu or ^{240}Pu oxides is essentially the same as for ^{238}Pu and ^{241}Am in the same form. While the comment is mathematically correct it is logically inconsistent. The EPA statement was based on the most soluble transuranics becoming available for incorporation into ten percent of the diet. A similar chain of events would lead to one percent incorporation for the less soluble oxides of ^{239}Pu and ^{240}Pu.

70. Department of Energy

Sentence implies that gonad deposition is important and that it is a primary site of deposition, second only to liver and bone; this is misleading. (p-18, lines 7-10)

Staff Response - In view of the relative importance of genetic consequences, the long retention of transuranics in gonadal tissue, and the possible micro deposition of transuranics adjacent to sensitive cells, the Agency believes the dose to gonadal tissues deserves careful consideration.

71. Department of Energy

It appears that calculations are made assuming that the source is continuously renewed and a constant amount taken in over the 70-year period. This is inappropriate when soil is the source, especially for the shorter-lived transuranics. (p-18, lines 21-24)

Staff Response - The Guidance document stated on page III-19 that "the occurrence of lifetime ingestion is remote". However, renewed contamination is not the only way long term exposures could occur since patterns for ingestion are a function of land use. The Tables are not the Guides. When doses are expected to decrease so that there is a high probability that the bone dose in the 70th year would not exceed 3 mrad, this should be considered in the implementation of the guidance.

72. Jefferson County Health Department

On page sixteen the report states "plutonium oxide found in the environment has been shown to be much more soluble than the refractory oxide utilized in animal experiments". The report states (page 19) that organ dose rates listed in Table A 3-6 were calculated on the basis of organ masses appropriate for a reference man but not for children. The report also states that there is some evidence from studies of newborn animals of a high rate of transfer of transuranium elements across the gut wall to blood. On page twenty-one the report notes that the transfer of americium and curium across the gut wall is about 100 times greater than for other transuranium elements. (p-16, line 19)

Staff Response - Contrary to this comment, age-specific dose calculations for ingestion based on organ masses for children were made and reported on page 20 and Table A3-9 of Annex III for the case of ingestion by infants, the limiting case. As pointed out in Annex III, children's organs are changing mass rapidly, so that the incremental change in total dose or in dose rate at age 70 was less than +10%. This was not considered enough difference to justify age-specific intake calculations. Dose rates and radiation risks for inhalation were calculated on an age-specific basis.

The statement on page 21 Annex III was misread. The statement is "Transfer of americium and curium to milk is about 100 times greater than other transuranium elements..." not that the transfer across the gut wall is 100 times greater.

73. Department of Energy

The reference to Section 3.4.3 is inappropriate, since this Section does not describe in specific detail how gonadal dose has been calculated. (p-19, lines 13-14)

Staff Response - Agreed, only the rationale was described in Section 3.4.3. However, see reponse to comment 60.

74. Department of Energy

This statement should be referenced. (p-19, lines 19-23)

Staff Response - High gut transfer of transuranics in the newborn is discussed in Reference (1), Annex III. Also in Section 6, W. J. Bair and R. C. Tompson, letter communication (1977).

The basic references include ICRP Publication 19 (1972); W. J. Bair, pp. 171-230 in WASH-1359, 1974; M. F. Sullivan and A. L. Crosby, BNWL-1950 (1975) and BNWL-2000, pt. 1 (1976). M. F. Sullivan, PNL-2500, Pt. 1 (1978) provides futher data.

75. Department of Energy

Ref. 15 appears to be an error. (p-20, line-7)

Staff Response - Reference 15 is a misprint. Reference 25 is correct.

76. Department of Energy

This argument should be further developed, since the referenced paper is not readily available. How different were the doses, and was the possible promoting effect of cigarette smoking controlled? (p-22, lines 1-7)

Staff Response - The material referenced is also discussed by R. W. Cihak, et al., Cancer, 33:1580-1588 (1974)) under the same title. A follow-on article on Smoking, Occupation and A-bomb Exposure (T. Ishimaru, et al., Cancer, 36: 1723-1728 (1975) reports that a Mantel-Haenzel analysis of four-fold tables indicates that the reduction in (Chi) when adjusted for smoking"...is not large enough to suggest a confounding of smoking with radiation dose..." The most these authors could conclude was that the data they had did not by itself provide any suggestion of non-additivity of the effect of radiation and the effect of smoking, when those exposed at less than 1 rad and those exposed at 200+ rads, were compared.

77. Department of Energy

Reference 35 is another critical reference which is unpublished, and Annex 4 does not describe the procedures employed in sufficient detail to check the accuracy of the Table A 3-10 and subsequent similar tables. (p-24, lines 14-16)

Staff Response - The life table analysis used by the Agency is a straightforward application of the risk assessment methodology developed by the NAS-BEIR Committee to prepare their summary tables of effects, see particularly Table 3.1, 3.3, and 3.4 in the 1972 NAS BEIR Report. The EPA analysis is based on a stationary population and risk of particular rather than all cancers. A general description of the model was given in Annex IV of the Guidance document.

78. Department of Energy

It is not clear what is meant by "averaging the geometric means". (p-25, lines 3-5)

Staff Response - Adding the geometric means and dividing by two.

79. Department of Energy

While it is impossible to check the calculation because of unpublished critical references, it should be noted that the lung cancer risk listed here is about 5 times higher than either the Medical Research Council's (England) estimate, or the estimate of ICRP Publication 26. (p-25, lines 14-15)

Staff Response - The MRC adopted the 1972 BEIR Committee's lowest risk coefficient, 1 case per 10^6 person years at risk per rem and 25 years at risk for occupational exposure. The EPA analysis is not based on occupational exposure and necessarily considered a longer period of risk, i.e., lifetime risk. Moreover, EPA utilized BEIR estimates of the risks due to exposure during childhood, a factor not considered by the MRC. The Agency has also included estimates based on the relative risk of radiogenic cancer. The ICRP gave no information on how they derived the risk estimates published in ICRP #26. Since they were considering occupational exposure, their analysis may have had much in common with that of the MRC.

80. Department of Energy

"140 bone cancers per 10^6 rad " (p-26, line-16)

Staff Response - Agreed. There was a misprint. 140 bone cancers per 10^6 rad is correct.

81. Department of Energy

Marshall's statement should be referenced. (p-26, line-23)

Staff Response - The appropriate reference for Marshall et al.: J. H. Marshall, P. G. Groer and R. A. Schlenker "Dose to Endosteal Cells and Relative Distribution Factors for Radium-224 and Plutonium-239 Compared to Radium-226", presented at the 1976 Alta Symposium, Health Physics, in press.

82. Department of Energy

The bone cancer risk employed is considerably lower than the estimate one would derive from the BEIR Report. Should this not be acknowledged? (p-28, lines 13-15)

Staff Response - The EPA bone cancer risk estimates are somewhat larger than those prepared by the 1972 BEIR Committee on the basis of earlier data. The estimates of bone cancer are risk based on human exposures due to ^{244}Ra. The BEIR absolute risk estimate for ^{224}Ra is 9.6 sarcomas per 10^6 skeletal rad per year at risk, (page 128 of the 1972 BEIR Report). However, as the BEIR Committee pointed out on page 127 of their Report, long-term exposure to ^{244}Ra increases the incidence per rad by a factor of about two. Since transuranics incorporated into bone yield chronic not acute exposures, the EPA estimate is based on prolonged exposure, i.e, 25 per 10^6 skeletal rad per year at risk, (page 28 of Annex III).

83. Department of Energy

Dose values shown in Table A 3-11 apparently assume continuous input over 70 years; if so, this is inappropriate, particularly for soil contamination by the shorter-lived transuranics. (p-29, lines 8-10)

Staff Response - See response to comment 57.

84. Department of Energy

The reason given for not considering "relative risk" for bone cancer is not clear. (p-29, lines 11-16)

Staff Response - The human data for the persons treated with ^{244}Ra indicates a finite plateau period; in such case, use of an absolute risk model is warranted. By definition a relative risk model assumes that the time pattern for the occurrence of radiogenic cancers is the same as that for the "naturally" occurring cancer.

85. Department of Energy

Bone cancer risks of Table A 3-12 apparently assume continuous input over 70 years, which again would be inappropriate, particularly for soil contamination by the shorter-lived transuranics. (p-29, lines 22-23)

Staff Response - See response to comment 57.

86. Department of Energy

Sentence is not clear. (p-29, line-23 to p-30, line-2)

Staff Response - The sentence is poor. The point to be made is that even though the risks from 3 mrad alpha dose to the bone in the 70th year, following continuous ingestion of ^{239}Pu or ^{241}Am are similar, (see Table A 3-12) the dose per unit of activity ingested is 10 times higher for ^{241}Am than for ^{239}Pu (see Table A 3-7). Therefore, the maximum amount of ^{241}Am that could be ingested under the Guidance would be 10 times less than the amount of ^{239}Pu that could be ingested.

87. Department of Energy

Statement is misleading. The magnitude of the potential risk was inferred from animal data long ago. It has received support, more recently, from Thorotrast patients. (p-30, lines 15-17)

Staff Response - The possibility of liver cancer associated with actinides but not the magnitude of risk was shown by animal experiments. The Agency prefers to use human experiences as a basis for risk estimates and support this with animal data where necessary.

88. Department of Energy

Statement regarding the abundance of animal data should be referenced. (p-31, lines 21-25)

Staff Response - References to animal data on liver cancer induced by plutonium should include: L. A. Buldakov, et al., Problems in Plutonium Toxicology LF-tr-41, 1970; G. N. Taylor et al., pp. 105-127 in Radiobiology of Plutonium, 1972; G. N. Taylor, et al., pp. 523-536 in The Health Effects of Plutonium and Radium, 1976.

89. Department of Energy

Reference 15 appears to be an error. (p-32, line 21)

Staff Response - Reference 15 is an error. Reference 6 should be indicated.

90. Department of Defense

Reference (15) discusses gonadal tissue, not liver. (p-32, line-21)

Staff Response - See response to comment 89.

91. Department of Energy

The concept of an equilibrium dose from a short-lived transuranic is not consistent with a single-event contamination. (p-33, lines 11-14)

Staff Response - See response to comment 57.

92. Department of Energy

The ICRP factor of "20" should be referenced to ICRP Publication #26. It is a Quality Factor "intended for use only in radiation protection and then for comparing actual levels of exposure with the limits of dose equivalent... These values of Q are therefore not necessarily representative of values of relative biological effectiveness for other observed effects, such as stochastic effect in animals at low levels of absorbed dose". (emphasis added). If the number 20 is to be used as an RBE, not as a Quality Factor, it should be justified. (p-34, line 7-10)

Staff Response - Agreed. Scientific evidence supporting the Agency's choice of RBE of 20 compared to x-rays was provided in the Guidance document. (Reference 45, Annex III).

93. Department of Defense

There is a loose association here between RBE and QF. The ICRP does not assign an RBE of 20 for alpha, it says the QF is 20 for radiation protection purposes. (p-34, line-7)

Staff Response - See response to comment 92.

94. Department of Energy

The origin of the factor "5" in "100 (5x20)" is not clear. (p-35, line-1)

Staff Response - The reduction in genetic effects due to low dose rate low LET radiation in the 1972 BEIR Report is 3.4 for males and infinite for females. Because the Agency is unconvinced that low dose rate, high LET particles will not affect the genetic competency of mature oocytes, the factor of 3.4 was arbitrally increased by 50 percent to 5.

95. Department of Energy

This sentence is misleading. The "other analyses" are supported by only a single reference, and the "underestimate" is relatively insignificant compared with the overestimate alleged in Ref. 49. (p-35, lines 8-10)

Staff Response - Although, as Ash, *et al.* point out: "The question of whether multifactorial disorders should be considered in assessing the risks of ionizing radiations is one of semantics, for if multifactorial diseases are maintained by mutations, they are essentially monogenic." (Ash, *et al.*, J. Med. Genetics, 14:305-306 1977). The Agency has treated multifactorial genetic disorders as distinct entities.

References for the possible underestimate of multifactorial disease in the 1972 NAS BEIR Report include: Development of Common Indices for Radiation Health Effects, Final Report to EPA, A. D. Little, Inc., 1974; Sources and Effects of Ionizing Radiation UNSCEAR Report, 1977 and abridged versions of papers presented at an MRC forum on hereditary disease in man, Journal of Medical Genetics, 14:305-331, 1977.

96. Department of Energy

Limiting gonadal dose to 30 years is a "population risk" assumption that has questionable applicability to a "critical segment" analysis. (p-36, lines 4-6)

Staff Response - See response to comment 64.

97. Department of Energy

This same caveat applies also to all other calculations of dose from ^{244}Cm in this Guidance and should be discussed in connection with these other calculations. (p-36, lines 12-14)

Staff Response - Agreed.

98. Department of Energy

Pertinent animal data on leukemia risk from transuranics is ignored. (p-37, Section 3.9.1)

Staff Response - Pertinent animal data on leukemia from transuranics was not ignored. It is summarized in Reference 51 by Dr. Vaughan. However, the application of animal data on radiation-related leukemia has been summarized by UNSCEAR-1977 as follows, "In view of the diversity of these syndromes myeloproliferative and lymphoproliferative diseases and in the absence of any indication as to whether and to what extent any of them might be akin to human leukemias, attempts to identify the nature and the number of cells at risk on the basis of our present knowledge may only be regarded as an 'academic pursuit'."

99. Jefferson Country Health Department

Leukemia due to bone marrow irradiation (page 37). The report states that for a three millirad limiting dose to bone marrow, the leukemia risk ranges from 0.4 to 1.6 cases per 100,000 exposed, for the absolute and relative risk models, respectively. This is apparently based on the fact that the leukemia mortality due to excess radiation is about 1/5 of all radiation-induced cancers. This estimate is considerably less than my own and seems not to be a conservative estimate (4). (p-37)

Staff Response - No. Effects from total body irradiation were estimated from the leukemia risk, not the other way around. However, the leukemia risk estimates in Annex III contain a computational error. Revised risk estimates for leukemia are presented in Section 6.1.

There is also a typographical error on page 37, Annex III, line 24. The sentence "For a 3 mrad limiting dose to have in the 70th year,..." should read "For a 3 mrad limiting dose to bone in the 70th year,..."

100. Department of Energy

There is no basis given for the suggestion that "7% of actinides (are) distributed in the body tissue after inhalation;" such a statement should be referenced. The argument of the paragraph seems specious, since a total body transuranic dose has no meaning, and the "early deaths due to leukemia indicated in Table A 3-17" were not based upon total body plutonium. (p-38, lines 3-11)

Staff Response - Further information on the derivation of the estimate of 7% of actinides distributed in soft tissues is given in Reference (1) in Annex III.

The basic rationale is that ICRP-19 estimates that 10% of plutonium (or other actinide) transferred to blood is deposited in soft tissue and excreta. From Durbin's reports on plutonium distribution in man (P. W. Durbin, pp. 469-530 in Radiobiology of Plutonium, 1972; P. W. Durbin and N. Jeung pp. 297-313 in The Health Effects of Plutonium and Radium, 1976); the distribution of injected plutonium in animal tissues other than skeleton and liver, is about 15.5% and in excreta 6.1%, i.e., a ratio of activity in soft tissue to that in excreta that is approximately 70% to 30%. That 7% of blood plutonium is in soft tissue is a reasonable estimate, is supported by McInroy's observation that in tissues of occupationally-exposed individuals, the total body burden is distributed as follows:

Lung	28.2%	±	22.6%
Skeleton	47.5%	±	29.3%
Liver	18.1%	±	15.3%
Tracheobronchial Lymph Nodes	4.7%	±	4.6%
Other Soft Tissue	7.0%	±	10.9%

(J. F. McInroy, pp. 249-270 in The Health Effects of Plutonium and Radium, 1976).

101. **Department of Energy**

It is not stated how the "estimated range of between 3 and 30 early deaths" is arrived at, but it presumably derives from the highest and lowest values of the four different BEIR models, in which case it is not a range of risk, but simply the range of different estimates, each of which have a very large (and basically unquantifiable) uncertainty. The statement is misleading since it implies that at least three deaths will occur in the cohort of 100,000. (p-38, lines 16-18)

Staff Response - The Agency agrees with the first part of this comment. The range indicated is simply the range of different estimates, each of which have a large uncertainty.

The Agency does not believe the statement concerning either the minimum or maximum risk to be misleading. As a best judgment based on current knowledge, the Agency does not believe that the uncertainty in risks can be substituted for a postulated threshold so as to presume zero effects for finite doses.

102. **Department of Defense**

Footnote is not tied to table, no reference for table which is true for many of the tables in this annex. (p-49, Table A 3-5)

Staff Response - All comments on table are largely correct but editorial in nature.

103. **Jefferson County Health Department**

On page thirty-eight (summary of health risks) the report estimates that the total somatic and genetic risks due to inhalation of transuranium element aerosols causing an annual dose to the pulmonary region of one millirad per year (20 millirem per year). The estimated cancer risk to one million people is 90 premature deaths, with an estimated range of 30 to 300. An annual dose to the pulmonary region of one millirad per year is roughly equivalent to 20 millirem per year to the lung, 960 millirem per year to tracheobronchial lymph nodes, 60 millirem to bone, about 30 millirem to liver, 4 millirem to kidney and one millirem to gonads. In my opinion, this dosage would result in about 110 excess deaths due to leukemia and a total increase in all neoplasms of perhaps 1 to 2% over a period of seventy years. The incidence of all genetic diseases could increase by 1% and ill health related to chromosome mutation by about 7% for all succeeding generations from this dosage level.

Staff Response - The commentor has errored in his interpretation and use of the 1972 BEIR Report, see response to comment 21 submitted by the same commentor.

104. Department of Energy

"Genetic Risk" requires definition in terms of the kind(s) of effects the numbers refer to. Without further definition they might be interpreted, erroneously, as "premature deaths". (p-62, Table A 3-18)

Staff Response - The genetic risk estimates referred to are those characterized as "Serious Disabilities" pages 55 and 56 of the 1972 BEIR Report. These include: dominant diseases, e.g., Cowden's disease or Von Recklinghausen's disease; congenital abnormalities, and such constitutional and degenerative diseases as anemia, diabetes, schizophrenia and epilepsy, but not heart disease, cancer, or ulcers.

105. Department of Energy

The "range" column is misleading. It should be clearly indicated that these are not ranges in the usual sense of upper and lower limits, or the result of some statistical measurement, but are simply the highest and lowest of the numbers derived from different models. (p-62)

Staff Response - See reply to comment 101.

106. National Council on Radiation Protection and Measurement

The dose rate calculations are performed assuming a constant intake over a lifetime. This may apply to the effluent from a processing plant and to ^{239}Pu in soils but not for the other nuclides in soils because of their relatively short half-lives.

We recommend the inclusion of tables for the nuclides that take into account the decrease in soil concentration with time due to radioactive decay.

Staff Response - See response to comment 57. Changes in activity level must be considered on a site-specific basis since radioactive decay is only one factor. Transport of contaminating material into or out of the local biosphere may be more important.

107. Ilene Youngheim

I do not understand your terms Relative and Absolute in regard to risk, such as Table A 3-10. I can understand the absolute premature deaths being less than the relative premature deaths, but why would the average years of life lost to premature deaths be less (for relative risk), 18.4, than for absolute risk, 22.0.

Staff Response - Relative and Absolute refer to the form of the assumption underlying the projected numbers of expected cancer deaths. The question addresses the measures of the lifetime health risk due to lung cancer mortality induced by pulmonary doses.

The absolute risk estimates assume that the incremental lung cancer mortality resulting from exposure to transuranium elements increases in direct proportion to the dose, and is independent of the natural incidence of lung cancer. The relative risk estimates assume that incremental increases are related to both the level of exposure and to the natural incidence rate for lung cancer in the U.S. population (i.e., risk is proportional to the product of the exposure level and the natural lung cancer mortality rate). The use of relative risk models implies that radiation interacts with other factors that contribute to the natural incidence of cancer.

The differences in the average years of life lost to premature deaths assuming relative and absolute risk is a result of difference in the age distributions of the projected lung cancer deaths. U.S. mortality statistics show that lung cancer is a cancer of old age, hence fewer years of life lost per cancer death are predicted in relative risk calculations.

108. Ilene Youngheim

Annex 3, 3.1. It is possible that your estimation of effects on gonads has been underestimated. Plutonium has concentrated in the gonads of animals pasturing close to the Rocky Flats Plant.

Staff Response - The Agency staff believes that its evaluation of genetic effects in humans resulting from plutonium inhalation or ingestion accurately reflects the viewpoints of experts in this field. The presence of plutonium in the gonads of cattle grazing on contaminated soils is expected, but is not necessarily comparable to uptake and distribution by humans.

109. Jefferson County Health Department

The report states (page 34) "for reasons given below, genetic damage from alpha particles is expected to be about a factor of 100 greater than that assumed in the BEIR Report. Bas[illegible] on current recommendations of the ICRP, alpha particles are 20 times more damaging than x-irradiation for a number of biological endpoints, including genetic effects. This is not necessarily over-conservative, since an increase of about 20 compared to x-irradiation has been reported for genetic damage from highly ionizing neutron irradiation." In addition, there is some opinion that the 1972 BEIR Report may have underestimated the amount of multifactorial diseases having a genetic component. However, despite these conservative assumptions on page 30, the report estimates that a 30 year dose of one millirad from alpha-emitting transuranium elements in genital tissue may cause only between 0.1 and two genetic defects per 100,000 live births in the first generation, with a potential in later generations of 0.6 - 15 defects per 100,000 live births. This figure seems to be inconsistent with estimates of risk to health posed by four millirem of radionuclides in the support document for the EPA Water Quality Regulations.

Staff Response - The basis for the genetic risk estimates is given in Annex III of "Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment." Similar estimates for genetic risk were presented in the support document for the EPA Drinking Water Regulations, EPA-570/9-76-003.

110. Jefferson County Health Department

On page twenty two the report cites a 1976 National Academy of Sciences Report which states that the absolute risk (the number of cases that will result from exposure of a given population) estimate for bronchial cancer in uranium miners is 20 cases per million organ-rad per year at risk, and not 10 as indicated in the 1972 BEIR Report. The number of lung cancers from alpha radiation at a given dose appears to be increasing as the years at risk in relevant epidemiological studies are extended. The relative risk estimate (the ratio of the risk in those exposed to the risk to those not exposed) in the 1972 BEIR Report also is likely to be low. "Assuming that the relative risk for U.S. miners is increased in a manner similar to the absolute risk, it would be comparable to the 1972 BEIR estimate for Canadian miners who have been similarly exposed." That is a 6% increase in annual incidence per rad. The 1972 BEIR Report assumes a 15-year latent period (10-20 years) for all solid tumors induced in both children and adults.

Staff Response - The staff agrees.

3.4 Annex IV - Risk Perspective

1. Department of Energy

A more specific reference would be helpful. (p-1, lines 8-9)

Staff Response - The reference is to the brief description of the general characteristics of the life table methodology. A more detailed description of the life table methodology is available. (See Comment 3)

2. Department of Energy

"Cohort" should be defined. (p-1, line 14)

Staff Response - A cohort is a group of individuals of common age. The lifetime mortality experiences of cohorts of 100,000 individuals are used in this analysis.

3. Department of Defense

This section indicates that EPA has developed its own methodology, which is unavailable, but which may be changed. This precludes any reasonable attempt to evaluate its validity and in effect, is an unacceptable situation. (p-1, Section 2)

Staff Response - EPA did not intend that the discussion of the life table and its methodology would give the reader the impression that the methodology would be changed in the future. A description of the life table methodology is available. See J.R.Cook, B.M. Bunger, and M.K. Barrick, "A Computer Code for Cohort Analysis of Increased Risks of Death", EPA 520/4-78-012, USEPA, Washington, D.C. (1978)

4. Department of Energy

It is not clear what, or whose, "methodological differences" are referred to, or why. The sentence is confusing. (p-2, lines 14-16)

Staff Response - There is a difference in methodology between removing a risk from the life table and adding a risk to it.

5. Department of Energy

The Life Table Methodology referenced, as well as the methodology actually employed, should be made available in order to understand the procedures used. (p-4, lines 7-10)

Staff Response - See response to Comment 3.

6. Jefferson County Health Department

The purpose of this annex is to make the excess death rates due to exposure to radiation appear more acceptable by comparing them with death rates from diseases and accidents presently experienced by the U.S. population. The effects of radiation are further compared to effects from background radiation received by the U.S. population, about 100 millirem to the whole body. The implication given is that if a person is receiving radiation of the same order or less than the background radiation he is already receiving, that the additional increment is not really significant. This is not really the case, since it is felt that background radiation itself produces an effect on the population in terms of an increased rate of cancer and genetic defects. Adverse effects should not be considered more acceptable merely because there are other adverse effects to which we are exposed. (p-4, Section 3)

Staff Response - The purpose of this Annex is to provide information relevant to an evaluation by the reader of the acceptability of the limiting risk for the guidance recommendations. It clearly does not make the judgment of what constitutes an acceptable risk level, nor does it argue that an additional increment of risk is not significant.

7. Department of Energy

Since there is no table identified as Table A 4-1 in this Annex, presumably Table IV-1 is intended. (Similar comment applies to page IV-5, lines 4 and 10, and page IV-7, lines 10 and 14.) (p-4, line 23)

Department of Defense

Table designation does not conform to that of the table (A 4-1 vs IV-1). Same applies to other tables. (p-4, line 23)

Staff Response - All references to tables in Annex IV should have been designated with the prefix IV instead of 4.

8. Department of Energy

Cautionary statements concerning the limitations of BEIR risk estimates are needed and should appear at this point. (p-4, lines 24-25)

Staff Response - The BEIR report is well known and accepted in the radiation protection field. We do not believe that cautionary statements concerning the limitations of the BEIR risk estimates are warranted.

9. Ilene Younghein

Annex 4, p.6 "Exposure to 1 mrad per year is therefore estimated to have a much smaller lifetime impact than does background radiation." I should hope so! If death rates, life shortening, and gentic damage become as prevalent from plutonium as from background radiation, we would really be in sad shape. There is one vital difference though. We are stuck with background radiation, it is a risk we can do almost nothing about. The risk from plutonium is a risk that we have added on to the risk from background. It probably is erroneous to talk of life shortening and premature deaths in terms of background radiation. They are part of the basic formula at birth. Better to talk of life lengthening if we could devise a way of doing without it. (p-6)

Staff Response - We agree. The purpose of the guidance is to minimize the risk to persons in the general population from exposure to a single potential radiation source. The recommended risk is well below that from background radiation. Numerical values are given to provide a perspective.

10. Department of Defense

It is not surprising that the life shortening is approximately the same for both forms of risk because the calculational method employed was the same. The point is missed by this reader. (p-7, line 7)

Department of Energy

That "the life shortening is approximately the same for both forms of risk" would be expected because it was calculated the same way for both. (p-7, lines 7-8)

Staff Response - The comment is incorrect. The life table method takes into account the age distribution at time of death. Since the dose to various organs from inhaled and ingested transuranium elements is highly time dependent, it can be expected that the age distribution at death, for organ specific causes of death, will differ for each organ. Therefore, predicted life shortening for different types of exposure (background radiation, inhalation and ingested transuranium elements) is not expected to be the same for all cases analyzed by the life table method.

11. Department of Energy

The relevance of this material is not established. (p-7, section 4)

Staff Response - Section 4 addresses the comparison of other forms of risks of death generally experienced by members of the population to the risk from exposure to transuranium elements.

3.5 Annex V - Guidance Implementation

1. Department of Defense

While the Agency may believe "that these recommendations can be implemented...without requiring...unreasonable, unnecessary, and expensive regulatory actions," the analyses required to show that this is true have not been done. Such a statement should be referenced to a study or studies showing this to be a fact. (p-2, lines 1-3)

Department of Energy

There is a great disparity between the EPA's belief that the recommendations can be implemented without requiring unreasonable, unnecessary and expensive regulatory actions and the actual case of implementing. Certainly the supporting material has not presented a convincing case that implementation would not be expensive. This is a prime example of taking liberties between fact and supposition. (p-2, lines 2)

Nuclear Regulatory Commission

The conclusion that the proposed guidance would be capable of implementation at reasonable cost to licensees is not adequately supported by the information provided in the EPA Technical Summary Document. Further, the statement in the *Federal Register* Notice that the Guidance is capable of implementation at reasonable cost is in conflict with the earlier statement, in Rationale for Guidance, that EPA has found that costs of remedial actions will differ so greatly between contaminated sites that generic cost-benefit guidance cannot be provided. More discussion should be presented to support the conclusion that the cost of implementing the guidance at the reference level of soil contamination is, in a generic sense, reasonable.

Staff Response - The agency staff has evaluated the status for all existing sites of known transuranium element contamination in the United States, and has concluded that it is very unlikely that large-scale remedial actions will be required to ensure compliance with the guidance recommendations. Therefore, regardless of the cost of remedial actions per unit area, the total cost of implementation for existing sites is judged to be reasonable and achievable. In view of the above, and the alternatives available to the implementing agency, the agency staff staff believes that the statement is fully valid.

Costs of remedial actions for sites which may become contaminated in the future are considered in Sections 4 and 5.

2. Department of Energy

In the area of administrative implementation, there is a lack of unambiguous definition of the choices permitted, and the circumstances under which they are permitted. Three general procedures for implementing the Guidance are set forth on p. 2 of Annex V, but one of these is identified as the "preferred method," which could make it administratively very difficult to choose any other. Actually, there can be no predetermined preferred method, since the preference will depend upon the site-specific information obtainable and cost-benefit considerations.

Method "a" may not be the "preferred" method. Preference is determined by the information obtainable and cost-benefit considerations. To label one method as "preferred" will make it administratively very difficult to employ any other method. (p-2, line 10).

Staff Response - The intent of the Agency is to maintain flexibility in implementation of the Guidance. Methods which introduce the cost ambiguity are generally to be preferred, consistent with the site-specific information available, necessary time constraints, and other similar factors. The agency staff staff believes that public acceptance of any administrative decision is largely determined by a full and complete disclosure of all information and that, on a technical basis, any of the proposed methods provides an acceptable implementation procedure.

3. Department of Energy

Where flexibility is not permitted, requirements should be precisely stated; where flexibility is permitted, advice must be carefully worded to avoid compromising the intended flexibility. The proposed Guidance is notably deficient in this critical area.

EPA should either leave this choice entirely to the agencies having regulatory and administrative responsibilities for the site in question, or specify which of these clearly defined procedures should be employed for each of several categories of clearly defined incidents; this would reduce the flexibility but simplify the administration.

For example, soil sampling to a depth of one centimeter is specified, though the sampling of any reasonably sized area to this depth is virtually impossible under field conditions; sampling and preparation of soil samples should employ "a method which does not cause the breaking up of soil aggregates," but it is doubtful if such a method exists; and acceptable maximum chance of a wrong decision in evaluating soil contamination levels is suggested to be 5-10%, although there is no assurance that such precision is possible under any reasonable circumstances; air sampling programs should "ensure that air concentration levels are representative of actual exposure conditions," but no such sampling procedures exist; all methods employed must "have the necessary sensitivity, accuracy, and precision for purposes of implementing this guidance," but the necessary sensitivity, accuracy and precision are nowhere defined.

Staff Response - The agency staff believes that some uniformity of approach is essential for proper interpretation of the results. For that reason, generalized sampling and analysis procedures are suggested which can be expected to give results appropriate for use in the decision making process. Such generalized procedures obviously must be adapted to local conditions, and it is the responsibility of the responsible Federal agency to choose procedures which will best satisfy the implementation criteria of the Guidance. It is acknowledged that precise adherence to the suggested procedures may be impracticable or even impossible, but these procedures should at least form the basis of a program of evaluation and major deviations should be justified.

The staff does not agree that sampling to a depth of about one centimeter is impossible for most types of terrain, and believes that soil preparation methods do exist which do not greatly change the physical characteristics of aggregates. Statistical sampling techniques are generally designed with a defined objective of accuracy and precision, and the frequency of sampling is determined accordingly. The time and resources required to achieve a 90-95% confidence level may sometimes be unreasonable, but deviations from this objective should be justified. The staff also believes that air sampling programs currently in use at several existing sites meet the specified criteria, and do satisfactorily measure annual average ambient air concentrations. The "necessary sensitivity, accuracy, and precision" of analysis techniques represents a judgment situation and is ultimately closely related to the overall confidence level required.

4. Department of Energy

If these procedures are available they should be referenced. The available procedures are largely concerned with the evaluation of population averages and are not appropriate to consideration of the "critical segment." (p-5, lines 2-6)

Staff Response - The statement refers specifically only to measurement, and not to calculational procedures. Application of the guidance recommendations to a "critical segment of the population" may require knowledge of site-specific population or land use characteristics.

5. Department of Energy

It is not clear what this sentence is trying to say, but the several reasonable possibilities all seem to be incorrect. It provides little guidance unless "in close proximity to" is given more specific definition. (p-8, lines 8-11)

Staff Response - The intended meaning is that the particulate content of air is mostly derived from surface materials located at some distance from the point of measurement, and only a small fraction is that resuspended from the immediately adjacent area.

6. Department of Energy

If there is a method "which does not cause the breaking up of soil aggregates" it should be referenced. (p-12, lines 9-11)

Staff Response - The intended meaning is to avoid deliberate breakup of aggregates by milling or grinding in those samples designated for particle size analyses.

7. Department of Energy

A single reference seems inadequate for this entire subject. (p-12 lines 13-20)

Staff Response - A more detailed discussion of Guidance implementation is provided in Section 5.

8. Department of Energy

The statement that a 5-10% maximum chance of error is "generally considered appropriate" leaves one uncertain as to whether EPA will consider this an appropriate criterion. If this is, in fact, the criterion, it is a very important part of the Guidance and requires further discussion. (p-14, lines 12-14)

Staff Response - The staff believes that a 90-95% confidence level generally represents a realistic objective for environmental measurements. We do not think that further discussion is required.

9. Department of Energy

For how long is "stabilization" considered effective? (p-16, lines 7-12)

Staff Response - Stabilization is a temporary measure, designed to prevent dispersion during the initial phase after deposition when the material is most mobile.

10. Department of Energy

It seems inappropriate that an Annex on implementation includes only four references, two of which are not referred to in the text.

Staff Response - The comment seems to misinterpret the intent of this Annex. The staff believes that the implementing Federal agency has primary responsibility for evaluating the situation and for choosing the appropriate remedial actions. The principal purpose of this Annex is not to provide a technical implementation manual, but rather to give sufficient information to members of the general public to let them judge the feasibility (and problems) of implementation.

11. Department of Defense

"Much greater or much smaller" has no precise meaning and is therefore useless. (p-3, line 19)

Staff Response - The terms are relative and interpretation is at the discretion of the implementing agency.

12. Department of Defense

Reference the procedures and indicate their acceptability for use in compliance. (p-5, line 2)

Staff Response - See response to comment 10.

13. Department of Defense

This entire Annex is so vague and contradictory that it is essentially useless. It can only result in controversy, confusion and possible litigation. Several examples illustrate this:

(a) Page 14, line 21: In effect, it says you can choose a statistical method to give the results desired.

(b) Page 11: Says ingestion of dirt may need consideration because of importance, but in Annex II, this route is considered of no importance.

Staff Response - The staff does not agree that Annex V is vague and contradictory, and believes that it serves its intended purpose (a) The paragraph referred to says that, where acceptability of an area is in doubt, decisions are best based on statistical tests. (b) The sentence in entirety reads "the more unusual transfer methods to people .... may need to be examined if shown to be of importance."

14. Jefferson County Health Department

On page 5, emphasis is placed on the annual average transuranium element concentration in air. However, air sampling devices may not provide an accurate estimation of the potential risk to residents of areas contaminated with plutonium.

Staff Response - The staff believes that the annual average concentration of transuranium elements in air is the best indicator of the inhalation hazard to persons from chronic exposure. The accuracy of measurements will need to be evaluated for each specific occurrence.

15. Jefferson County Health Department

In the last paragraph on page 9, the Agency again appears to support the use of resuspension factors, which were reported earlier to have a variability of as much as one million. The use of such a factor, it seems to me, is very questionable.

The guidelines recommend that soil samples should be taken to a depth of one centimeter and the transuranium element activity measured in the particles less than two millimeters in size. This sample, as I have pointed out previously, is inappropriate for evaluation of a respirable dust hazard. In addition, I do not feel, as the Agency does, that samples may be composited for a single measurement. If this is done, hot spots will be undetected when averaged with many other locations with lower levels of activity. I find these guidelines to be unacceptable. The best way to evaluate a hazard from airborne contaminated dust is by use of respirable dust sample from the surface of the soil.

Staff Response - (a) The staff does not specifically support use of a resuspension factor, and recommends that the relationship between soil and air concentration be determined by use of the mass-loading calculational method. (b) The staff does not support the use of Dr. Johnson's "respirable dust" sampling method and believes it to be inappropriate for implementation of this Guidance (see Section 7). (c) Compositing of several samples for chemical analysis is a generally used and accepted technique. "Hot spots" are of importance only to the extent that they change the uptake by an individual.

16. Jefferson County Health Department

On page 12, the report mentions "the usual method for determining distribution of soil particle sizes is by sedimentation analysis" and then cautions that "soil characteristics should be altered as little as possible in the collection and preparation of the soil sample, and care should be taken to choose a method which does not cause the breaking up of soil aggregates that were present when the sample was taken." This statement appears very strange when we consider that the alternate method used by the EPA, Rocky Flats and the Colorado State Health Department involves the use of agricultural soil samples which are dried and pulverized to a fine powder in a steel ball mill.

Staff Response - The comment apparently confuses two entirely different aspects of the evaluation, namely size distribution of particles and chemical analysis of the soil samples. Retention of soil physical characteristics is essential only for the determination of the particle size distribution, while reduction to a fine power is a preliminary step in the chemical analysis procedure.

17. Department of Energy

It has not been shown that "most of the potential hazard is derived from contamination at, or near, the surface." This depends upon the depths of the disturbances possible in the area. The contention that "most man-made disturbance will reduce the concentration in the top layer" may not be true if levels higher than those permitted by the Guidance have been reduced by mixing through the top layers. In such a case, further disturbance will gain nothing. (p-4)

Staff Response - We agree with this comment but would point out that the conclusion is applicable only to the choice of remedial actions and does not change the rationale for the Guidance.

18. Department of Energy

A major ambiguity surrounds the administrative aspects of determining and certifying compliance with the Guidance. It is implied that reports must be made, but never stated to whom. It is recommended that remedial action be taken quickly, but requirements for environmental impact assessment, evaluation of area contaminated to a precision of 5-10%, sampling of air at weekly intervals, sampling food, etc., will preclude quick action.

Department of Energy

To whom do the Federal agencies "certify that Guidance values...are not being exceeded?" At what level above background is such certification required? In other words, what triggers this procedure? (p-4, lines 11-14)

This paragraph discusses vaguely defined requirements, with no indication of which entity will be responsible for those requirements. A definition of reports required, and to whom they should go, is not discussed in this Guidance. (p-11, lines 7-13)

Department of Defense

To whom do the Federal agencies certify that guidance values are not being exceeded? What is the process, time requirements, administrative procedures, etc.? It is not made clear here or elsewhere. (p-4)

Staff Response - No reporting requirements for this Guidance exist at present, but the Agency may establish such requirements at a future date.

It is not the intent of the Guidance to require administrative procedures that would preclude prompt remedial actions in the event of a contaminating event.

19. Department of Energy

This sentence seems to assume that there is a particle size distribution characteristics of a specific site. Actually this distribution will vary with wind speed, soil moisture, dust brought from off-site, mechanical disturbance, etc. To obtain any realistic measure is a very long and expensive procedure. It is not clear that such intensive study, which can only be performed at a few points, would be cost-effective. (p-5, lines 12-13)

Staff Response - We agree that the sentence is ambiguous. It is intended that the implementing agency use site-specific data to the maximum extent practicable, without going to the extreme of a long-term research effort.

20. Department of Energy

This sentence is unrealistic. Many current studies are indicating the complexity of environmental solubility considerations. Predictions in this area are extremely uncertain. In any case, the only guidance given in Annex III is for Class Y compounds. (p-5, lines 15-20)

Staff Response - We disagree with the conclusion that the sentence is entirely unrealistic, at least to the extent that the solubility class of most transuranium elements in the environment can be inferred from their history or other data. However, the comment is correct in that major uncertanties do exist and it cannot a priori be assumed that Class Y (insoluble) is applicable in all cases. A discussion of the changes introduced by Class W (soluble) compounds is given in Section 6.

21. Department of Energy

Sentence is more intelligible if "into" is changed to "in." However, the relationship implied in the sentence is not established. (p-7, lines 5-7)

Staff Response - The reference is to the greater availability of transuranium elements biologically incorporated into plants or animals (See Annex III)

22. Department of Energy

Perhaps the most serious ambiguity is that surrounding use of the soil screening level. Its use is appropriately recommended in the Summary Report (p. 29) as a procedure that "can serve to reduce the land area requiring evaluation and minimize the number of measurements needed." In Annex II (p. 25) it is stated that the screening level "will identify land areas where no additional monitoring is required." But in discussion of the soil screening level in Annex V (p. 9) it is stated that "In all cases the cumulative doses to the critical segment of the population must be considered," which will require the complete characterization of the contaminated area that the soil screening level was designed to avoid. Again, in Annex VI (p. 11), it is stated that in the off-site areas adjacent to the Rocky Flats plant, "more intensive evaluation may be needed to determine the actual dose rates to the general population," this despite the fact that the soil screening level is not exceeded (as indicated on p. 10). In Annex V (p. 8) it is stated that "the screening level concept may not be applicable when the soils of a contaminated area contain these nuclides (Am and Cm) in amounts greater than 20% of the total activity." The potentially very useful concept of a soil screening level has thus been compromised by vague references regarding its inapplicability under various circumstances, to the point that it is doubtful whether its use could ever be justified.

It is suggested in this paragraph that a conservative "derived air concentration limit" be employed as a test of compliance, when other approaches are "difficult or impossible." If a simple cheap comparison to an air "screening level" is possible, why go to the expense of unnecessary site-specific evaluation. This is the expressed philosophy on which the soil screening level is based. It would seem that the "air screening level" should be similarly considered and included along with the soil screening level in the Summary Report. (p-15, line 21)

This says that in all cases you must do everything, which contradicts the philosophy of screening levels. (p-9, line 9)

It is stated that "the screening level concept may not be applicable." (p-8, lines 12-17)

Staff Response - The intent of the "screening level" is as stated, namely to exclude from detailed evaluation those areas where contamination is sufficiently low so that there is little possibility that resultant doses to persons would exceed the guidance recommendations. This judgment is based on calculations which have considered both the inhalation and ingestion pathways, but which may not have included some very exceptional circumstances. The presence of more than 20 percent of the total activity as americium or curium, which are more soluble and therefore represent a greater ingestion hazard, is such an exception. Therefore, the staff believes that the admonition to consider such exceptions, where warranted, is both valid and indicated.

The air screening level provides assurance only that Guidance levels are not exceeded through the inhalation pathway. The use of such an air screening level is not precluded by the Guidance implementation procedures.

23. Department of Energy

The "derived air concentration limit" must be based on singularly defined parameters. The specified AMAD is presumably 0.1 um. The phrase "not to exceed" therefore seems inappropriate. While conservatism is perhaps justified in the derivation of such a "screening limit," the unrealistic AMAD of 0.1 um would seem to be excessively conservative. (p-6, lines 2-6)

Staff Response - An AMAD of 0.1 micrometer may be used if measured values are not made for the specific site under consideration. We do not believe this value to be excessively conservative because the difference in dose calculated using an AMAD of 0.1 micrometers compared to the more "realistic" value of 0.5 micrometers is only a factor of 2.

24. Department of Energy

"Disturbed sites" are not addressed. These are part of the exposure potential and should not be overlooked. (p-11, lines 15-19)

Staff Response - The "disturbed site" was addressed in the derivation of the soil screening level (Annex II)

25. Nuclear Regulatory Commission

The alternative remedial action of establishing restricted access or use of the area in question is not discussed in the Federal Guidance. We propose that, at least for future contaminating events, the guidance state that this alternative not be used, if at all possible.

Staff Response - Remedial action choices are the responsibility of the implementing agency. However, we agree that it is preferable to clean up a future contaminating event and that simply establishing restricted access should not be used if at all possible.

26. Nuclear Regulatory Commission

We are concerned that the proposed reference level of soil contamination which is presented in the statement of consideration as a screening level, "based on limited data available for several existing sites," may be interpreted as an effective action level. Discussion of the reference level in the presentation of the modeling methodology used in the backup document appears to be sufficient.

Staff Response - We agree that the screening level should not be considered an effective action level.

27. Nuclear Regulatory Commission

In order to clarify that the operative guidance for newly contaminated areas are the dose rates specified in paragraph one of the text of Proposed Guidance, we recommend that the second sentence of paragraph two be deleted.

Staff Response - We disagree. The intent of the second sentence is to make it clear that not only is the dose to be minimized but that remedial actions are to continue until doses are projected to be well below the guidance levels. It is not likely to be possible to verify compliance within a time frame comparable with the time needed for the remedial action. A degree of conservatism is justified.

28. National Council on Radiation Protection and Measurements

We recommend that the actions following a future possible accident be better defined and that a study be made to show that these limits are appropriate.

We recommend that this Annex be rewritten with careful consideration of the practicality and cost of the requirements and that a specific section on implementation following accidents be included.

Staff Response - Comments on the proposed guidance have supplied valuable additional information on the potential costs and effectiveness of remedial actions for possible future contaminating events. These are discussed in Section 4 and 5 and the Agency has concluded that the Guidance is appropriate for future contaminating events.

29. Jefferson County Health Department

This screening level value is not conservative, and does not provide adequate protection to the public. In my opinion, residents of areas with this degree of contamination will be unwilling to accept the effects of such exposure.

Staff Response - We disagree. In our opinion the screening level is conservative. There is no evidence that residents of areas contaminated to levels below the screening level will be unwilling to accept the very small potential risks.

30. Jefferson County Health Department

The report notes that the choice of suitable methods for sampling and analysis is the responsibility of the agency implementing the guidance. In the case of the area around Rocky Flats, there may be several such agencies involved in this implementation, i.e., the Health and Safety Laboratory of the Department of Energy, the State Health Department, and the Jefferson County Health Department. It would be desirable for the agencies to agree on a standardized approach.

Staff Response - We agree.

31. National Council on Radiation Protection and Measurement

The Implementation Annex provides a number of general statements as to methods of assuring that the guidance is met. A number of these appear to differ from similar statements in other Annexes and the general impression left is one of confusion as to what should be done and how well. There is no specific implementation for accidental releases so that one can only conclude that the entire Annex will apply.

We recommend that this Annex be rewritten with careful consideration of the practicality and cost of the requirements and that a specific section on implementation following accidents be included.

Staff Response - Annex V is intended to provide generalized guidance on methods appropriate for assuring compliance with recommendations. In the absence of more specific information on where conflicting advice is given, no answer can be provided on this comment.

Evaluation of the consequences of possible accidents, and of the need for remedial actions, should follow the same general procedures as outlined in this Annex. However, time constraints on initiating actions are expected to be more stringent for instances of new contamination.

32. Department of Energy

To avoid lengthy future contention over what this Guidance does, or does not mean, it is recommended that the entire document be carefully reviewed to eliminate inconsistencies and ambiguities; and that Annex V be rewritten in a clear and simple fashion, being careful to recommend only those procedures whose applicability has been demonstrated, and to avoid comment on procedures that are left to the discretion of the Agency implementing the Guidance.

Staff Response - Refer to comment 31.

33. Department of Defense

The intent and impact of this sentence appears ambiguous, while "unnecessary cost" may be avoided, the "necessary" cost may be very large. (p-2, lines 20-23)

This is a misleading oversimplification of the proper objective unless it is made clear that "cost" includes such items as dislocation of people, environmental damage and other non-monetary costs. The mention of non-monetary costs earlier in the paragraph is not adequate to prevent this misinterpretation. (p-15, lines 17-20)

The very important non-monetary costs considered in these paragraphs should not only be considered in deciding between alternative cleanup procedures, but should be balanced against the risks of no remedial action at all. (p-18, lines 13-21)

These psychological costs, which receive only passing comment in the last sentence of this Annex, must be considered to be a serious risk involved in transuranic contamination of the environment. Many of the actions that might be taken to reduce other risks may increase the fear that leads to these psychological costs. (p-18, lines 20-21)

Staff Response - Economic considerations are described in Section 4. Non-monetary and psychological costs are difficult to quantify.

34. Nuclear Regulatory Commission

It appears that the costs of taking remedial action for facilities licensed by this Agency would substantially exceed the lower limit value of $500 per acre assumed for the proposed guidance. For example, disposal of surface soils by burial in commercial low-level waste burial sites would probably equal or exceed the costs of the general per cubic foot charge for burial. Using a value of $3 per cubic foot (NUREG-0217) would result in an estimated cost of $5000 per acre for burial charges alone.

Some NRC licensed facilities are located in areas having other buildings and structures which would be substantially more costly to decontaminate than for a facility located in a remote area. A recent "Draft Engineering Evaluation of the Latty Avenue Site, Hazlewood, Missouri," by Ford, Bacon, and Davis, Utah, Inc., dated January 1978, indicates that the five remedial action alternatives evaluated for the 18,300 cubic yards of contaminated material at the 10 acre site, range from $457,000 for cleanup and temporary storage of contaminated materials on site to $4,131,000 for the alternative of disposal at a commercial nuclear waste disposal site. These estimates are comparable to the data presented in Table VI-2 of the EPA Technical Summary Document.

Staff Response - We agree that the costs of remedial actions would generally greatly exceed $500/acre (See Section 2.3, comments 7, 8 and 9). The numerical estimates provided are very useful and give an additional perspective applicable to decisions on implementation options.

EDITORIAL COMMENTS - The following comments were accepted but were considered editorial in nature.

Department of Energy

Page V-6, lines 9-12

The admonition to seek site-specific data seems to be inconsistent with the qualification of the first sentence of this paragraph, which says the method is to be employed only when site-specific data are "difficult or impossible" to obtain.

Page V-7, lines 19-23

"Under such conditions" requires definition. On the previous page "characterization of the source term" is considered necessary only "when these levels approach that of the Guidance recommendation." Here the qualification is lost.

Page V-11, lines 1-4

This sentence seems to contradict the discussion on p. 17 of Annex II where the significance of children eating dirt was dismissed because it required "extreme assumptions."

Page V-12, Section 5.1.1

No reference is provided.

Page V-14, lines 21-24

This sentence would be improved by eliminating the last four words. As it stands, it seems to say you can prove whatever you want with statistics. Appropriate references should be provided.

Page V-15, lines 1-9

This paragraph introduces for the first time, without definition, terms such as "true fraction," "lower bound," and "upper bound." This leads to confusion, since the paragraph appears to acknowledge that portions of land area may reasonably exceed the limiting soil concentration. Extensive rewording is suggested.

Page V-15, lines 15-17

Not all transuranics have long half-lives.

Page V-16

It is very easy to misinterpret this page as a listing of always available alternatives among which one chooses on the basis of site-specific costs. It should be made clear that at many sites many of these options would not be available.

Page V-17, lines 10-13

This sentence is not clear. It should be reworded or deleted.

3.6 Annex VI - Environmental Assessment

1. Department of Defense

It is not clear whether the reference to NEPA is in the context that EPA has to file an EIS for the proposed Guidance or that the various agencies who will be involved in clean-up have to file an EIS. Clearly, for major Federal actions, an EIS is required, thus, it is assumed any cleanup of any magnitude would require such a statement. Which is the case being presented? The relationship is not distinct. Clearly, if an EIS has to be filed before any cleanup is undertaken, the various requirements will cause delay in acting. What is done in the meantime--stabilization, evacuation of people, etc. This section serves to confuse rather than clarify. (p-1)

Staff Response - Implementation of the Guidance is the responsibility of the agencies having site jurisdiction or causing environmental contamination. In the event of future incidents, it is assumed that proper and expeditious remedial actions appropriate to the occasion will be taken. For existing situations, where time is not a critical factor, the evaluation of all impacts and alternatives should be considered and the preparation of an EIS might well be an integral part of the decision making process.

2. Department of Energy

This paragraph would seem to require an Environmental Impact Statement or Assessment before any cleanup action is taken. Thus, in compliance with Annex V, the area must be surveyed to a precision of 5-10%, uptake in potential food crops measured, air samples taken at weekly intervals, etc. A dose assessment must then be made and alternatives considered, taking account of monetary, societal, and environmental costs. All of this could take from one to several years. Thus, if any land is contaminated by transuranics (presumably) to any level and for any size area), the area must be stabilized and restricted until all this is done. If the above description is not the impression intended, the paragraph should be rewritten to clarify the intent. (p-1 ,lines 20-26)

Staff Response - The Guidance does not state the requirements for an Environmental Impact Statement. Such a requirement may be dictated by the magnitude of contemplated remedial actions, and appropriate discisions in this regard must be made by responsible State and Federal officials. It is intended that such decisions be governed by common sense and a concern for the health and safety of the population, rather than by a strictly legal interpretation of the guidance document.

3. **Department of Energy**

At some point mention should be made of the possible complications posed by an endangered species living in a contaminated area. (p-2)

Staff Response - Such detailed evaluations must be considered on a site-specific basis.

4. **Department of Energy**

"Temporary disruption of normal activities" is a very optimistic way of describing the more realistic description of the previous comment. (p-2, line 7)

Staff Response - The magnitude of adverse impacts is a function of the scale of remedial actions. "Temporary disruption of normal activities" is intended to apply to that range of anticipated remedial actions which could be expected to occur for events with a higher probability of occurrence.

5. **Department of Energy**

"Animals...and fauna" is redundant. (p-2, line 9)

Staff Response - We agree.

6. **Department of Energy**

The fact that the detailed study of ecological impacts will not be received until the end of 1977 implies that this Guidance was formulated without knowledge of such detailed impacts. (p-2, lines 17-20)

Staff Response - True. The Guidance was derived on the basis of health impacts, not a detailed knowledge of ecological impact for remedial actions. Such knowledge would be most useful for evaluating alternatives of remedial actions, which is beyond the scope of the Guidance.

7. **Jefferson County Health Department**

If the guidance from the International Commission on Radiation Protection is to be considered I think it is important to know who is on the commission, which industries or agencies they represent, and whether the members have signed statements of disclosure concerning financial and other interests which may impinge on their duties as commission members. (p-5)

Staff Response - The recommendations of the International Commission on Radiation Protection have been rejected as inappropriate for this Guidance. Therefore, the remainder of the comment is irrelevant.

8. Department of Energy

Whether these values are "unacceptable" would depend upon the probability of exposure from other sources. If all sources of exposure are very unlikely, any one of them should be allocated a major fraction, if not all, of the limit. This seems to be a basic area of disagreement between the philosophy of this Guidance, and what other respected bodies consider to be a more reasonable philosophy. (p-5, lines 9-13)

Staff Response - The rationale and limitations for the statement are given in the remainder of the paragraph. The Agency does not agree that higher dose rate limits, with or without the principle of dose allocation, represent a "more reasonable philosophy."

9. Department of Energy

Does the Guidance permit this? "Could well be acceptable" is not sufficiently precise. (p-5, lines 13-15)

Staff Response - The Guidance is intended to permit, and even encourage, some judgment on the part of the implementing agency.

10. Department of Energy

It would be helpful if the Colorado standard was interpreted in terms of units more directly related to the EPA Guidance. (p-5, lines 21-23)

Staff Response - The Colorado Guidance is stated on a legally defined basis and cannot be converted to other units without introduction of certain assumptions. The EPA guidance is not stated in terms of a soil concentration level, and correlations must be made on a site-specific basis.

11. Jefferson County Health Department

Reference is again made to the present standard of 2 dmp/g of dry soil adopted by the State of Colorado in 1973, representing about 25 times average plutonium fallout background for Colorado. Unfortunately, the standard does not define the meaning of the word "soil" which has been taken to mean agricultural soil. I agree that the Colordo standard cannot be considered in the context to long-term public health protection, since it is neither well defined nor conservative. (p-5, line 22)

Staff Response - The Guidance recommendations refer to dose rate limits, and reference to a "soil standard" is inappropriate and erroneous.

12. Department of Energy

The intended meaning of these two sentences is not clear. (p-6, lines 4-10)

Staff Response - The intended meaning is to acknowledge that the Colorado standard may serve as a reasonable means of protection for construction workers and that the objective of public health protection is not given as its primary purpose.

13. Department of Energy

See Department of Energy comment of page VI-1. (p-7, lines 23-25)

Staff Response - The sentence states that "if is important that a detailed environmental impact evaluation be made...prior to implementation." The comment probably confuses this admonition with the requirement for an Environmental Impact Statement. The above statement again illustrates the need for judgment on the part of the implementing agency.

14. Department of Energy

This section considers the projected impact of guidance at existing sites. Should there not be a section that considers the impact at hypothetical future sites of contamination, since this Guidance is designed also to apply to future contamination events? Several typical accidents should be analyzed, ranging from the maximum to a more normal release, occurring in several types of areas. This would indicate whether costs are in the range of thousands or billions of dollars, and given some indication of societal and environmental costs. (p-8, Section IV)

Staff Response - The agency staff believes that the consequences of potential accidents should be considered in the Environmental Assessment of similar evaluations for specific facilities and/or activities (e.g., transportation of fuel elements), but not part of a generic guidance.

15. Jefferson County Health Department

The report states that "the present maximum permissible lung dose rate of one millirad per year is equivalent to about 100 times the current contamination levels derived from fallout." This can be contrasted with the Colorado standard, i.e., about 25 times fallout.

I emphatically disagree that soil concentration data of plutonium at Rocky Flats indicates that offsite areas are "probably in compliance with the guidance." This is not supported by survey data. I would agree that "more intensive evaluation may be needed to determine the actual dose rates to the general population." Again in Table 6-1, I would disagree with the estimates of the area contaminated offsite. My recent report to the Jefferson County Board of Health of a survey of the contamination over the entire area demonstrates a large area with contamination greater than 100 times background and a much larger area with contamination 25 times background level.
(p-8, Section IV)

Staff Response - The conclusion that offsite areas at the Rocky Flats Plants are "probably in compliance with the guidance" must be characterized as tentative and subject to confirmation. It is based primarily on extensive environmental monitoring data by both the U.S. Department of Energy and the Colorado Department of Health, and includes evaluations of air concentrations and soil contamination levels as input for suitable calculational models to derive dose rates to exposed individuals.

16. Department of Defense

Annexes V and VI devote little effort to remedial action costs and uses $500/acre as an estimated cost. This cost is grossly unreasonable and underestimates actual expense involved in many cases for existing sites. A specific example is Enewetak where clean-up cost is at least an order of magnitude greater. Of equal importance are costs that could be incurred for sites that may be contaminated in the future, for a different set of circumstances could be involved. For instance, populated areas might be involved, requiring evacuation, personal property decontamination, stoppage of industry, restriction of agriculture and others. Certainly, this would involve costs associated with the project and could exceed the $500/acre associated by the EPA with the proposed Guidance. Would this, if considered, have made any influence upon the level chosen for dose limitation? Actual operating experience, at least in one instance, does not support the EPA conclusion "...that the cost of implementing the guidance at the reference level would be reasonable and achievable".
(p-10, Table VI-1)

Staff Response - The agency staff considers Enewetak to be a special case that need not necessarily fall under this guide. One reason is that the restriction of access to the contamination site is an option to be considered under this guide, but this option cannot be considered for Enewetak. The $500 per acre is a minimum, and was not intended to imply that all remedial measures can be performed at this cost. The recommended guide establishes what is believed to be an acceptable level of risk at a cost that is not believe to be unreasonably high. Costs of treatment for existing and possible future sites are discussed in the Supplement to the Proposed Guidance and Dose Limits for Persons Exposed to Transuranium Elements in the General Environment.

17. Department of Energy

Table conveys a false impression because of the unrealistic cost estimate. It also appears unreasonable that changing the "reference level" by a factor of 3 could have such a major effect on the area requiring remedial action. (p-10, Table VI-1)

Staff Response - Estimates of cost of remedial actions are speculative at best and cannot be derived on a generic basis. For the relatively low environmental contamination levels presently existing outside the boundaries of these facilites, the costs of remedial actions could be expected to be of the order of magnitude stated.

The estimates of areas defined within contamination contour lines were derived from published environmental monitoring data.

18. Depatment of Energy

Why is the population of the area relevant? The screening level seems to be independent of the number of people affected. Or is it to be understood from this sentence that such considerations are relevant? (p-11, lines 5-6)

Staff Response - The population at risk is a factor in evaluating the total impact of a given hazard.

19. Department of Defense

Again, the $500/acre cost is not generically realistic and dose not consider many factors such as decontamination of buildings, machinery, homes, loss of productivity, planning, etc. (p-13, Section V)

Staff Response - The $500 per acre figure was a minimum. Costs of treatment for existing and possible future sites are discussed in the Supplement to the Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment.

20. Department of Energy

This section presents an inadequate consideration of costs of remedial action. It says "the Agency has evaluated the available methods and costs" but does not tell how this was done, nor does it give any reference to this study. The results are presumably summarized in Table VI-2, which is difficult to read. It is clear, however, that in these estimates no consideration has been given to costs of population evacuation, or monitoring; decontamination of homes, roads, or commercial areas; income losses from cessation of agricultural or commercial activities; cost of Environmental Impact Assessment; to mention but a few. Nor does it give any consideration to environmental costs. (p-13, Section V)

Staff Response - The complete sentence reads "The Agency has evaluated the available methods and costs for cleanup and restoration of contaminated land areas." Most of the items cited may represent additional or extraordinary costs, and do not necessarily represent a cost of implementation of the Guidance.

21. Nuclear Regulatory Commission

Some NRC licensed facilities are located in areas having other buildings and structures which would be substantially more costly to decontaminate than for a facility located in a remote area. A recent "Draft Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri", by Ford, Bacon, and Davis, Utah, Inc., dated January 1978, indicates that the five remedial action alternatives evaluated for 18,300 cubic yards of contaminated material at the 10 acre site, range from $457,000 for clean up and temporary storage of contaminated materials on site to $4,131,000 for the alternative of disposal at a commercial nuclear waste disposal site. These estimates are comparable to the data presented in Table VI-2 of the EPA Technical Summary Document. (p-14, Table VI-2)

Staff Response - We agree that this range of costs is reasonable.

22. Department of Energy

Table requires a number (presumably VI-2), a title, enlargement to readable size, and particularly, appropriate references. (p-14, Table VI-2)

Staff Response - The basis, data, and content of Table VI-2 are given in "Selected Topics: Transuranium Elements in the General Environment", EPA Technical Note ORP/CSD-78-1 (1978).

4. ESTIMATED COSTS OF REMEDIAL ACTIONS

4.1 Introduction

The primary costs of implementing the Guidance are the costs of bringing all sites exceeding the recommended soil limit into compliance. These include presently existing contamination sites as well as sites that may become contaminated in the future. The costs of decontaminating presently existing contamination sites are believed to be small, so that the major costs of implementation are expected to be incurred in the event of future accidents or incidents that release transuranium elements to the environment. Since the potential sites of future accidents cannot be identified, a procedure is used for estimating an upper limit to the expected annual costs of remedial measures.

There are a number of difficulties in determining the appropriate measures for attaining compliance for contaminated lands. The major difficulty is that there has been little experience with the decontamination of soils contaminated with transuranium elements. Thus there is little expertise for determining the appropriate action to be taken to reduce the contamination level on a given piece of land to an acceptably low level. In addition, the determination of the appropriate procedure requires information on site-specific factors that are best determined from on-site analysis by persons familiar with the task to be carried out and the resources available. It is especially difficult to determine the appropriate remedial measures for new accidents, where it is important that prompt action be taken to restrict dispersion of transuranium elements into the environment.

4.2 Cost Estimation

Since the Guidance requires that the maximum individual dose be at or below a specified limit, and does not specify specific remedial actions, cost-minimization is the appropriate criterion to identify the preferred set of remedial actions from the set of actions that will bring the site into compliance. The total cost of each possible set of options that can attain compliance should be evaluated to determine the least-cost method. Environmental costs and other non-monetary costs not quantifiable in monetary terms should, if possible, be considered in the evaluation. Whenever feasible, it is desirable that costs be quantified monetarily, but if this is not feasible, they should be quantified in non-monetary terms. Narrative descriptions should be used when no quantification is possible. A difficulty is that different combinations of decontamination procedures are expected to have somewhat different mixes of monetarily quantifiable, non-monetarily quantifiable, and non-quantifiable costs. Judgment must be used in weighting the different elements of these costs.

Most non-monetarily quantifiable and non-quantifiable costs are site specific. Because of the great difficulty in estimating these, especially in the event of future accidents, only the monetary costs of implementation will be discussed here. Cost of implementation is considered to be the monetary cost, on a nationwide basis, of performing the remedial measures sufficient to reduce the exposure to the critical segment of the population at each site to the recommended level.

Two sources provide the unit cost estimates used in this evaluation, an EPA study entitled "Available Technology and Unit Costs of Cleaning Plutonium Contaminated Land Areas," and a document entitled "Department of Energy Comments on Decontamination Costs Discussed in the EPA Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment" (Enclosure II to the Department of Energy's comments on the proposed EPA guide for transuranium elements in soil). Table 4.1 is reproduced from the EPA study. It summarizes the results of the study.

The Department of Energy has extensively analyzed the costs of remedial measures for lands contaminated with transuranium elements. Their estimates are used to supplement the EPA estimates because they consider a number of land use categories and decontamination procedures not considered in the EPA study.

Table 4.1 summarizes the estimated costs expressed in 1974 prices for a variety of cleanup measures. The costs shown in Table 4.2 are derived from Table 4.1, but are adjusted to 1977 prices.

Although costs of Table 4.1 have been assembled to facilitate the estimation of the unit costs of cleanup for different remedial action strategies, the costs of individual cleanup procedures are also available from the table. Table 4.3 presents the individual cleanup procedures costs (adjusted to 1977 dollars), derived from EPA estimates (Table 4.1) and from DOE estimates. Most of DOE's estimates were taken from Table 14 of their Enclosure II.1/ DOE costs have been adjusted to express dollars per acre.

1/ There are two errors in the costs shown in DOE's Table 14. Both are cost estimates credited to EPA. The first is that EPA estimates topsoil replacement to cost $4500 per acre, which is equivalent to $1,112,000 per square kilometer rather than $562,200 per square kilometer shown in Table 14. The second is in the cost of fencing. EPA estimates that fencing costs an estimated $30,000 per mile (1974 dollars) rather than the $3,700 per mile (i.e. $2,300 per kilometer) expressed in Table 14. Corrected cost estimates (adjusted to 1977 dollars) are shown in Table 4.3.

TABLE 4.1

Decontamination Costs

DECONTAMINATION TECHNIQUES →	STABILIZATION ONLY				REMOVAL WITH ONSITE DISPOSAL				REMOVAL WITH OFFSITE DISPOSAL AT A LICENSED BURIAL GROUND	
STEPS INVOLVED IN CLEANUP EFFORT ↓	1 PLOWING	2 CHEMICAL VEGETATIVE	3A SOIL COVER 6"	3B SOIL COVER 12"	4A SCRAPING INTO WINDROWS	4B SCRAPING INTO MOUNDS	4C SCRAPING INTO TRENCHES	5 VACUUMING WITH TRENCH DISPOSAL	6A SCRAPING	6B VACUUMING
A. RADIOLOGICAL SURVEILLANCE	(RANGE [illegible]) ASSUMED VALUE [illegible] (COSTS ARE ESTIMATED FOR A 3 MONTH PROJECT)									
B. STABILIZATION	[illegible] (ASSUMED [illegible]) [illegible] (RANGE [illegible]) (ASSUMED [illegible]) SHALLOW PLOWING RANGE [illegible] ASSUMED [illegible]	SHORT TERM STABILIZER FOR DUST CONTROL RANGE [illegible] (ASSUMED [illegible]) VEGETATION RANGE [illegible] ASSUMED [illegible] [illegible] OR LONG TERM CHEMICAL RANGE [illegible] ASSUMED [illegible]	SHORT TERM STABILIZER AND LOAM (RANGE [illegible]) (ASSUMED [illegible]) SHORT TERM STABILIZER AND TOPSOIL RANGE [illegible] ASSUMED [illegible]	SHORT TERM STABILIZER AND 12" LOAM (RANGE [illegible]) (ASSUMED [illegible]) SHORT TERM STABILIZER AND 8" LOAM 4" TOPSOIL RANGE [illegible] ASSUMED [illegible]	A) SHORT TERM STABILIZER APPLIED PRIOR TO SCRAPING OR VACUUMING FOR DUST CONTROL (RANGE [illegible]) (ASSUMED [illegible]) B) LONG TERM STABILIZER OR [illegible] RANGE [illegible] ASSUMED [illegible] OR B) VEGETATION RANGE [illegible] ASSUMED [illegible]		B) LONG TERM STABILIZER [illegible] RANGE [illegible] ASSUMED [illegible] OR B) VEGETATION RANGE [illegible] ASSUMED [illegible]	B) SOIL RESTORATION		
C. REMOVAL	NO SOIL REMOVAL COSTS				A) VEGETATION REMOVAL (OPTIONAL) GRASS COVER – (RANGE [illegible]) ASSUMED [illegible] SLIGHTLY WOODED – (RANGE [illegible]) ASSUMED [illegible] HEAVILY WOODED – (RANGE [illegible]) ASSUMED [illegible] B) SOIL REMOVAL (RANGE [illegible]) (ASSUMED [illegible])	B) SOIL REMOVAL RANGE [illegible] (ASSUMED [illegible])	B) SOIL REMOVAL (RANGE [illegible]) (ASSUMED [illegible])	B) SOIL REMOVAL (RANGE [illegible]) (ASSUMED [illegible])	B) SOIL REMOVAL (RANGE [illegible]) (ASSUMED [illegible])	B) SOIL REMOVAL (RANGE [illegible]) (ASSUMED [illegible])
D. PACKAGING	NO PACKAGING COSTS INVOLVED								IF MATERIAL IS TO BE SENT TO A 1) STATE BURIAL GROUND – RANGE [illegible] ASSUMED [illegible] OR A 2) FEDERAL REPOSITORY – RANGE [illegible] ASSUMED [illegible] NOTE – COSTS INCLUDE [illegible] TRUCK FREIGHT CHARGES, AND UNLOADING AT BURIAL GROUNDS.	
E. TRANSPORTATION	NO TRANSPORTATION COSTS INVOLVED				COSTS FOR FIRST 100 FT OF ONSITE HAUL INCLUDED IN REMOVAL COSTS. EACH ADDITIONAL 100 FT OF HAUL = RANGE [illegible] ASSUMED [illegible]				FOR MILEAGE IN EXCESS OF 100 TO 1000 MILES, COSTS ARE ADDED PER ADDITIONAL 100 MILES. FOR EACH ADDITIONAL 100 MILES RANGE [illegible] ASSUMED [illegible]	
ULTIMATE DISPOSAL	[illegible] MAY OR MAY NOT BE REQUIRED DEPENDING [illegible] FENCING FOR 10 ACRES = [illegible] RANGE [illegible] 20 ACRES = [illegible] RANGE [illegible] GUARD SERVICE – [illegible]/YEAR								IF THE MATERIAL IS TO BE MAINTAINED IN 1) NON-RETRIEVABLE FORM AT A STATE BURIAL GROUND RANGE [illegible] OR 2) RETRIEVABLE FORM AT A STATE BURIAL GROUND RANGE [illegible] OR 3) RETRIEVABLE FORM AT A FEDERAL REPOSITORY RANGE [illegible]	
F. RESTORATION	RANGE / ASSUMED (NO SOIL COSTS) FERT & LIME [illegible] STABILIZER [illegible] SEEDING [illegible] [illegible] OPTIONS OR ALTERNATIVES MULCH [illegible] GROUND COVER [illegible] SEEDLINGS [illegible] SHRUBS [illegible]	(RESTORATION COSTS INCLUDED UNDER STABILIZATION)	RANGE / ASSUMED (NO SOIL COSTS) FERTILIZER [illegible] TO STABILIZE [illegible] SEEDING [illegible] [illegible] OPTIONS OR ALTERNATIVES LIME [illegible] MULCH [illegible] GROUND COVER [illegible] SEEDLINGS [illegible] SHRUBS [illegible]	RANGE / ASSUMED (NO SOIL COSTS) FERTILIZER [illegible] STABILIZER [illegible] SEEDING [illegible] [illegible] OPTIONS OR ALTERNATIVES LIME [illegible] MULCH [illegible] GROUND COVER [illegible] SEEDLINGS [illegible] SHRUBS [illegible]	(RESTORATION COSTS ASSUMING [illegible] OF AN ACRE WILL REQUIRE SOIL) RANGE / ASSUMED LOAM [illegible] FERTILIZER [illegible] LIME [illegible] STABILIZER [illegible] SEEDING [illegible] [illegible] OPTIONS OR ALTERNATIVES TOPSOIL [illegible] MULCH [illegible] GROUND COVER [illegible] SEEDLINGS [illegible] SHRUBS [illegible]	(RESTORATION COSTS ASSUMING [illegible] OF AN ACRE WILL REQUIRE SOIL) RANGE / ASSUMED LOAM [illegible] FERTILIZER [illegible] LIME [illegible] STABILIZER [illegible] SEEDING [illegible] [illegible] OPTIONS OR ALTERNATIVES TOPSOIL [illegible] MULCH [illegible] GROUND COVER [illegible] SEEDLINGS [illegible] SHRUBS [illegible]	(ASSUMING SOIL FROM TRENCHES IS USED SO ONLY COST IS FOR APPLICATION) RANGE / ASSUMED SOIL APPLICATION [illegible] FERTILIZER [illegible] LIME [illegible] STABILIZER [illegible] SEEDING [illegible] [illegible] OPTIONS OR ALTERNATIVES TOPSOIL [illegible] MULCH [illegible] GROUND COVER [illegible] SEEDLINGS [illegible] SHRUBS [illegible]	(ASSUMING SOIL FROM TRENCHES IS USED SO ONLY COST IS FOR APPLICATION) RANGE / ASSUMED SOIL APPLICATION [illegible] FERTILIZER [illegible] LIME [illegible] STABILIZER [illegible] SEEDING [illegible] [illegible] OPTIONS OR ALTERNATIVES TOPSOIL [illegible] MULCH [illegible] GROUND COVER [illegible] SEEDLINGS [illegible] SHRUBS [illegible]	RANGE / ASSUMED LOAM [illegible] FERTILIZER [illegible] LIME [illegible] STABILIZER [illegible] SEEDING [illegible] [illegible] OPTIONS OR ALTERNATIVES TOPSOIL [illegible] MULCH [illegible] GROUND COVER [illegible] SEEDLINGS [illegible] SHRUBS [illegible]	
TOTAL PROJECT COSTS ASSUMED AVERAGES RANGES (NOTE: VEGETATION REMOVAL COSTS AND FENCING/GUARD SERVICE COSTS NOT INCLUDED; COSTS IN BRACKETS ARE THOSE USED TO CALCULATE TOTALS)	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]	STATE BURIAL GROUND NON-RETRIEVABLE AV [illegible] R [illegible] STATE BURIAL GROUND RETRIEVABLE AV [illegible] R [illegible] FEDERAL REPOSITORY RETRIEVABLE AV [illegible] R [illegible]	

TABLE 4.2

Decontamination Costs Derived From Table 4.1

Remedial Action	Disposal	Estimated Cost (1977 Dollars)
Stabilization & Restoration Only	In Place	$ 2,400/A
Shallow Plowing	Dilution In Place	3,000/A
Deep Plowing	Dilution In Place	2,850/A
4" Top Soil Cover	In Place	5,550/A
8" Loom & 4" Top Soil Cover	In Place	11,050/A
Scraping	Windrows on Site	4,150/A
Scraping	Mounds on Site	5,900/A
Scraping	Trenches on Site	5,550/A
Vacuuming	Trenches on Site	6,450/A
Scraping or Vacuuming	Off Site in State Repository	145,000 - 190,000/A
Scraping or Vacuuming	Off Site in Federal Repository	600,000/A

TABLE 4.3

EPA and DOE Unit Costs of Decontamination

Description	EPA Estimated Cost	DOE[a] Estimated Cost	DOE Definitions and Assumptions
Short term stabilizer	$ 810/A	$ 300/A	Two weeks water fixation
Long term stabilizer	690/A	420/A	Long acting stabilizer
Vegetation removal			
Corn	NE [b]	80/A	
Other Crops	NE	16/A	
Grass sod	580/A	920/A	Field sod removal
Slightly wooded	1,440/A	NE	
Heavily wooded	2,300/A	NE	
Soil removal			
Scraping	950/A	920/A	Grader
Front end loader	NE	1,700/A	
Manual labor	NE	2,900/A	
Vacuuming	1,210/A	NE	
Scraping into windrows	230/A	NE	
Scraping into mounds	690/A	NE	
Scraping into trenches	1,960/A	NE	
Vacuuming with trench disposal	2,890/A	NE	
Soil replacement			
4" topsoil	5,180/A	6,500/A	
4" loam	2,670/A	NE	
4" topsoil & 8" loam	10,700/A	NE	
12" loam	8,280/A	NE	
Shallow plowing (12")	50/A	14/A	25cm depth
Deep plowing (36")	230/A	140/A	1 meter depth
Deep plowing of pasture land	NE	610/A	Includes reseeding
Restoration			
Fertilizer	170/A A	270/A	Includes seed (materials only)
Lime	25/A	NE	
Mulch	140/A	NE	
Seeding	230/A	NE	See "Fertilizer"
Seedlings	70/A	NE	
Shrubs	1,500/A	NE	

TABLE 4.3 (continued)

Biobarrier	NE	72,000/A	
Lawn sod removal	NE	1,140/A	
Vacuumized sweeper for streets	NE	160/A	
Fire hosing	NE	200/A	
Decontamination of homes	NE	350/House	
Lawn resodding	NE	5,200/A	
Decontaminating commercial areas	NE	3,700/A	
Fence (based on perimeter length)	34,500/mi	75,600/mi	
Surveillance (based on perimeter length)	NE	9,700/mi	
Offsite disposal (including packaging) and 1000 miles tranportation)			
Federal Repository	586,500/A	482,500/A	
State Repository	138,000/A	59,500/A	Commercial repository (c)

(a) Taken from DOE Enclosure II, Department of Energy Comments on Decontamination Costs Discussed in the EPA Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the Environment, Table 14.

(b) NE - No estimate.

(c) Cost taken from document sited above. Reference found in footnote (a) to Table 10, p. II - 18

The two agencies' costs can be compared for those cases where both made estimates. The Table 4.3 shows that most estimates are within a factor of three. Although this is a rather big difference, it is no larger than might be expected considering the lack of experiénce with this form of decontamination. There is no apparent uniformity with respect to which agency's estimates are the higher. It can, therefore, be considered that EPA and DOE do not greatly differ in their estimates of the costs of the individual procedures that must be undertaken to restore transuranium contaminated lands.

There are two general techniques for restoring lands to unrestricted use: (1) all land surface soils are removed and transported to another location for final disposal; and (2) plowing, which leaves the contamination in place, but lowers the concentration levels in the top most land surface. When the surface soils have been removed, they may be stored on-site, or off-site in state or Federal repositories. On-site storage is an option that can be used where a part of the site can be reserved for the disposal of the surface soils removed from other portions of the site. In most cases it is estimated that no more than 5% to 10% of the site is needed for the disposal of the contaminated surface soils removed from the remaining 90 to 95% of the site. The part of the site used for disposal must be purchased and permanently subjected to controlled access, but there would be unrestricted access to the remainder of the site. An alternative that could be used for lands adjacent to a Federal facility would be that a portion of the facility grounds be reserved for the purpose of on-site disposal. On-site storage avoids the extremely high costs of off-site storage in state or Federal repositories. Tables 4.1, 4.2 and 4.3 provide estimates of the costs of on-site disposal. DOE did not consider this type of treatment.

Land use restrictions for entire contamination sites should be considered if such restrictions are the least cost option, although the circumstances of each particular site must be evaluated. Costs include acquisition of the site, the costs of fencing, guards, and any other measures required to maintain restricted access. Costs also include all remedial measures that may be required on the restricted area to prevent dispersion of the contamination to areas outside the restricted area, such as stabilization, plowing, the development of on-site storage in trenches, windrows or mounds, and the establishment of ground cover. Costs would also include the dismantlement of houses or other facilities that may be on the site.

Land use restrictions are a form of remedial action cost not quantifiable in dollars. Such restrictions are likely to impede the natural flow of traffic in the community in which they are used and to block its orderly development. Also, the restricted areas are likely to become despositories of trash and other waste as well as become overgrown with weeds unless there are ongoing maintenance programs. The disruptive nature of land use restrictions is so important, especially in urban or industrialized areas, that they are probably feasible only in localities of low population densities where there are few or no known alternative uses for the land.

DOE analyzed the cumulative costs of remedial action at three real (but unidentified) sites. Two area sizes were used at each site for a total of six sets of costs. The two sizes considered were $1km^2$ and $10km^2$. These sites are devoted to a number of uses, including crops, orchards, pasture, woodlots, forests, shoreline, and residential and commercial areas. The areas analyzed are quite large; large enough that DOE's cumulative decontamination costs are not realistic estimates of the cost of future accidents. Therefore, the total costs expressed in the third column of Table 4.4 are not useful for estimating the costs of future accidents. However, when these costs are expressed as functions of unit areas (i.e., $\$/km^2$ or \$/A), they serve as possible estimates of the average unit costs of future accidents.

The last column of Table 4.4 summarizes the average unit costs for the six sites analyzed by DOE. Most of the content of this table was taken from Table 13, Enclosure II. Alternative methods of treatment are given in the second column. Site restriction refers to the purchase of all lands and the maintenance of fences to restrict access to the entire contamination area and to the measures needed to prevent dispersal of transuranics. The other three treatments refer to the remedial action taken on open lands, where earth removal for off-site storage, shallow plowing, and deep plowing are alternatives. The remedial measures on all portions of these sites that cannot be plowed are the same for all three treatments. Reference site 2 had no open lands that could be plowed.

The mean and standard deviation for the four sets of remedial actions on the six sites are shown at the bottom of the table. Comparison of these values shows that for similar treatment strategies there is little difference in the average costs of treatment for the six sites, but that there are comparatively large reductions in costs when open lands are plowed. This demonstrates that measures that avoid the high cost of soil removal for final disposal in a state or Federal repository can significantly reduce the cost of remedial action. Calculations based on DOE's Table 11 and 12 (Enclosure II) show that off-site disposal at Federal repositories accounts for 82 to 98% of the costs of treating the six sites when earth removal is the treatment strategy.

TABLE 4.4

Comparison of Estimated Cumulative Costs per Unit Area for All Sites and Treatments*

Area	Treatment[a]	Total Cost ($ Million 1977)	Cost/acre ($ Thousand 1977)
1.0 km^2:			
Reference Site One	ER	115.6	468
	SR	95.2	385
	DP	12.9	52
	SP	11.4	46
Reference Site Two	ER	93.3	378
	SR	133.5	540
Reference Site Three	ER	121.2	490
	SR	95.4	386
	DP	21.2	86
	SP	19.5	79
10.0 km^2:			
Reference Site One	ER	1127.0	456
	SR	1062.4	430
	DP	159.5	65
	SP	145.2	59
Reference Site Two	ER	1103.1	446
	SR	1080.7	437
Reference Site Three	ER	1213.0	491
	SR	942.7	382
	DP	144.8	59
	SP	128.5	52

Average cost, earth removal (6 sites) = $454,000/A; standard deviation = $42,000
Average cost, site restriction (6 sites) = $427,000/A; standard deviation = $61,000
Average Cost, shallow plowing (4 sites) = $59,000/A; standard deviation = $15,999
Average cost, deep plowing (4 sites) = $66,000/A; standard deviation = $15,000

(a) ER = Earth removal to depth of 5 cm; DP = Deep (1-m) plowing; SP = Shallow (25-cm) plowing; SR = Site restriction, including construction of a biobarrier.

*Source: Enclosure II, Department of Energy Comments on Decontamination Costs Discussed in the EPA Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment, Table 13.

4.3 Recommended Action Levels

It would be useful to establish the contamination concentration levels at which different remedial actions are appropriate. Since a variety of circumstances bear on the determination, no universally applicable rules can be established. There is, however, some information for establishing the appropriate levels where some forms of remedial action may be considered.

The threshold of remedial action is established by the recommended soil screening level of 0.2 uCi/m^2. No remedial action need be undertaken, for sites with soil concentrations below this level.

The Department of Energy has established that shallow plowing (i.e. 10 inches) reduces the surface contamination by a factor of 5, to 20% of its former level, and that deep plowing (3 feet) reduces it by a factor of 20 to 5% of its former level.1/

Based on these estimates, and on the recommended soil screening level, it can be established that a contamination level equal 1.0 uCi/m^2 (before remdial action) is the upper limit for lands for which shallow plowing is sufficient to bring the site into compliance, and 4.0 uCi/m^2 is the upper limit for which deep plowing will attain compliance. Plowing is, of course, a viable option only for open lands where soil characteristics permit. Since deep plowing will bring sub-surface soils to the surface, some form of restoration, such as a soil cover of topsoil or loam may be required.

EPA estimates that land with a surface contamination below 10 uCi/m^2 (before remedial treatment) may be safely stored on-site in windrows, mounds or trenches. Such on-site storage requires that access to the storage area be controlled and that measures be taken to stabilize the surface soils from wind and water erosion. Controlled access is required to assure the soil surface is not disturbed and that the integrity of erosion prevention measures is maintained.

Other remedial measures are required for sites contaminated above 10 uCi/m^2. The most likely is the removal of the surface soils for transport to state or Federal repositiories.

It is possible that some of the very high costs of storage at state and Federal repositories can be significantly reduced by methods that concentrate the contamination, reducing transportation and storage costs. Concentration has been demonstrated for plutonuim,

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1/ Appendix C, pg. 6-4

where the major fraction of the plutonuim is generally attached to the smallest sized soil particles. This leaves the larger particle sizes, which usually constitutes the major fraction of the soil, relatively free of contamination. This subject is more fully discussed in Annex II to the "Proposed Guidance on Dose Limits for Persons Exposured to Transuranium Elements in the General Environment."

As discussed in the "Proposed Guidance", the soil screening level is conservatively chosen to provide that the recommended dose level be met for the most adverse soil characterstics. The recommended action levels have the same conservatism. Since these action levels are conservative, the circumstances of a particular site may be such that plowing or on-site storage may achieve the recommended dose limit for sites contaminated above the action levels derived here.

4.4 The Cost of Implementing The Guidance

There are two components to the costs of implementation. The first is the cost of bringing presently existing sites into compliance and the second is the cost of remedial measures undertaken for accidents that may occur after promulgation of this Guidance.

4.4.1. The Cost of Implementation on Presently Contaminated Sites

There are four Federal sites in the United States that presently have transuranium element contamination above ambient levels beyond their boundaries. These include the Rocky Flats Plant in Jefferson County, Colorado, Mound Laboratory in Miamisburg, Ohio, Nevada Test Site in southern Nevada, and Trinity Test Site near Alamogordo, New Mexico. The majority of all contamination released is confined within areas under the direct control of the Federal government, which imposes restrictions on the access and use of these areas. Relatively small amounts of transuranium element contamination exists outside the boundaries of these sites on lands generally accessible to the public. The following discussion is intended to supply a perspective for applying the Guidance recommendations to these sites in terms of a soil concentration reference level derived on the basis of generic data, which, with a very high degree of probability, would be expected to result in an inhalation dose to an individual not to exceed the Guidance recommendations. Use of such a soil contamination level is intended solely to provide a basis for comparisions and does not imply direct correlation with the dose rate recommendations. A brief description is given for each site and the general contamination pattern is indicated. Numerical comparisions to show the estimated areas of limiting contamination to one-third and one-tenth the reference level, and of allowing a value ten times greater than the reference level are given in Table 4.5. Comparisons are made in terms of areas outside the boundaries of these sites.

The Rocky Flats Plant produces components for nuclear weapons. Barrels containing cutting oil slowly corroded and some of the contents eventually leaked into the environment and were dispersed. On the basis of soil concentration data, all off-site areas at the Rocky Flats Plant would probably be in compliance with Guidance recommendations. However, more intensive evaluation may be needed to determine the actual dose rates to the general population, particualarly in the most highly contaminated areas east of the plant. The area is sparsely inhabited and there are few people living in the particular area of concern. The off-site area contaminated to a level one-tenth the screening level comprises about 1.6 mi^2 with a current population of less than 600. No uncontrolled areas are contaminated to a level greater than ten times the screening level. All local water supplies are expected to yield ingestion dose rates well below the Guidance recommendations.

Mound Laboratory is a major research and development site for fabrication of radioisotopic heat sources used for space and terrestrial applications. In 1969 a pipeline transporting a Pu-238 waste solution ruptured, spilling the contaminated solution. The plutonium migrated slowly into nearby waterways. The majority of the plutonium is now sorbed and fixed on the sediments of the North and South Canals. Maximum concentrations are to 1 to 3 ft. below the sediments surface and currently do not pose any radiation problem, since very little of the plutonium is in soluble form and the canal water is not used for drinking purposes. Banks immediately adjacent to the canal and overflow creek subject to occasional flooding have maximum plutonium concentrations exceeding the reference level. The amount of land in question is about 0.01 mi^2 and there are no people living on this land. There are no areas with transuranium element contamination 10 times the screening level. The amount of land contaminated to one-tenth the screening level is the same as the amount of land above screening level, because the nature of the contamination event limited the contamination to the waterways and adjacent banks. No immediate cleanup is indicated for this site, but continued surveillance will be required.

The Nevada Test Site covers an area of 1400 mi^2 with additional exclusion zone extending 16 to 48 miles. Major programs at NTS have included nuclear weapons tests, testing for peaceful uses of nuclear explosives, and nuclear reactor engine development. These activities have resulted in plutonium contamination in certain areas of the test site and exclusion areas and slight contamination (above background levels) outside the exclusion areas. There are no known uncontrolled areas which have transuranium element contamination exceeding the reference level. Land contaminated to one-tenth the reference level or less covers approximately 165 mi^2 with a resident popluation of less than 240 people.

The Trinity Test Site was the location of the first nuclear explosion. No other nuclear explosion tests were performed at Trinity. A site survey was performed by EPA during 1973-74 to determine residual plutonium concentration contours. The highest plutonium comtamination levels in uncontrolled areas ranged from 0.2 to 0.9 uCi/m^2. The amount of land contaminated to a level one-tenth the reference level covers less than 300 mi^2, with fewer than 500 people living in the area in small towns, ranches, and farms. On the basis of the limted available data, no major remedial actions would appear to be indicated for this site.

TABLE 4.5

Areas of Existing Sites Requiring Remedial Action for Several Possible Levels of Maximum Soil Concentrations

	Reference Level 0.2 uCi/m^2	10 Ref. Level 2 uCi/m^2	1/3 Ref. Level 0.07 uCi/m^2	1/10 Ref.Level 0.02 uCi/m^2
Rocky Flats Plant	0	0	200 Acres	1,000 Acres
Neveda Test Site	0	0	51,000 Acres	106,000 Acres
Trinity Site	0	0	13,000 Acres	192,000 Acres
Mound Lab.	0	0	6 Acres	6 Acres

In summary, it appears that few if any remedial measures are presently needed on the four sites identified in Table 4.5, although some action may be required when the canals at Mound Laboratory are drained. Therefore, the costs of meeting the Guidance for presently contaminated sites are expected to quite low.

An assumed minimum cost of $500 per acre for remedial action was the basis of the discussions in the "Proposed Guidance on Dose Limits for Person Exposed to Tansuranium Elements in the General Environment". This cost was introduced to demonstrate that, even if costs of remedial action were as low as $500 per acre, the costs of proposing a dose limit equivalent to a screening level substanially lower than 0.2 uCi/m^2 would be prohibitive. However, it is recognized that realistic estimates of costs of implementing the Guidance ordinarily must be based on unit cost estimates that are much higher than $500 per acre.

4.4.2. Considerations for Estimating the Costs in the Event of Future Releases of Transuranium Elements to the Environment

Strictly conceived, the costs of remedial measures required to implement this Guidance for potential future accidents are the costs over and above those that would have been undertaken in the absence of this Guidance. Unfortunately, this difference cannot be estimated. Therefore, to the extent that costs of required remedial measures can be estimated, they will be assumed to represent the costs of implementation.

The remedial measures available for the treatment of soil in case of future accidents are expected to be shallow or deep plowing, and soil removal with storage on-site, or in state or Federal repositories. In urban or industrial areas, houses, buildings, streets, and sidewalks may require decontamination. Temporary evacuation of the population may be also necessary. An alternative to restoring the land to unrestricted use is its acquisition, and the imposition of restricted access with possibly some form of remedial action undertaken on the site.

Although little can be done to anticipate the form of future accidents involving transuranium elements, they should impact on areas more limited in size than the largest of the presently known sites, which were caused by above ground tests of nuclear weapons. Since similar tests are unlikely in the foreseeable future, future contamination should be confined to areas smaller than the contaminated areas at the Trinity and Nevada Test Sites. It is to be expected that increased alertness to the problems of transuranium element contamination will substantially reduce the reoccurrence of events such as Rocky Flats, where the delay in treatment aggravated the situation. There is also reason to believe that increased awareness to the health hazards from transuranium elements has resulted in expanded effort to prevent the occurrence of such accidents. These measures should help to assure that the areas impacted in future accidents will be small.

The costs of remedial action in the case of future accidents are correctly conceptualized as the "expected costs" of the measures undertaken for all future events that release transuranium elements to the environment. As used here, the term "expected costs" is analogous to the statistical concept "expected value". Since there is at least a small probability that any of a large number of possible events releasing transuranium elements to the environment could occur in the future, and since there is a virtually limitless variety of factors contributing to the possibility of such events, expected costs are the appropriate measure of the costs required by the Guidance.

It can be argued that expected costs are the proper way to consider the problem from a societal point of view. Society is subjected to innumerable forms of financial risk from a variety of events. The events can be assumed to occur randomly; therefore the evaluation of the costs incurred because of such events should take into account the estimated probability of their occurrence as well as their costs when they do occur. Since the accidents that may release transuranium elements to the environment also occur randomly, the costs of required remedial action are one of these financial risks.

Probabilistic expressions of the chance of future accidents involving the release of transuranium elements, and of their size and the types of land to be impacted are needed to evaluate expected costs.

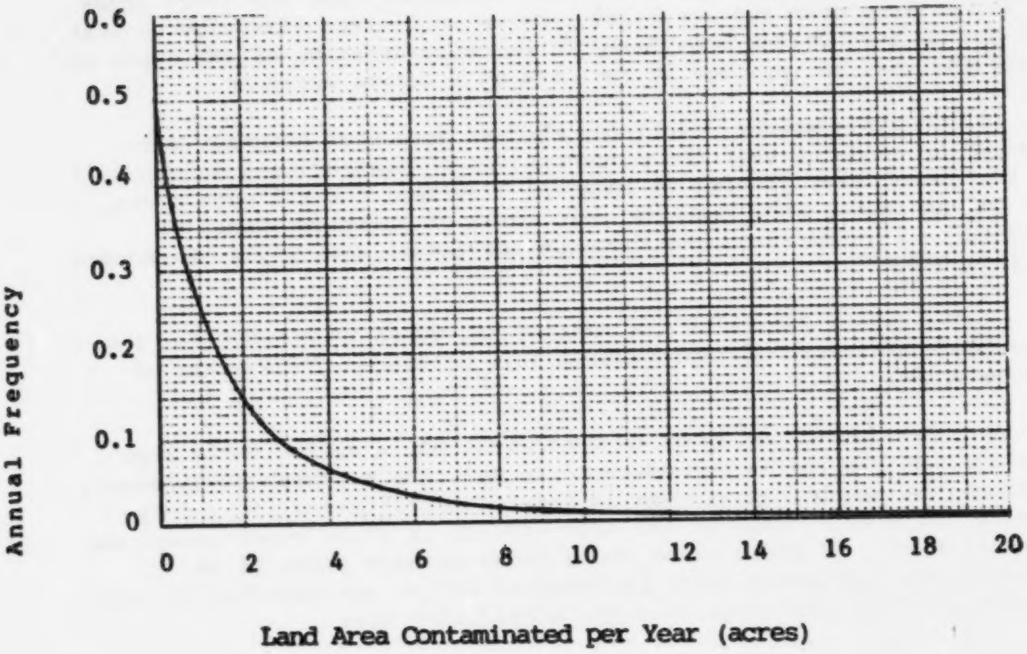
Another factor that may enter into the evaluation of the costs of implementing this Guidance is whether present worth methods should be employed in estimating the costs of possible accidents that may occur sometime in the future. If so, the estimated distribution of the probability of occurrence through time would be needed. Since no attempt has been made to estimate this distribution, present worth methods are not used here.

4.4.3. The Cost of Implementation in the Event of Future Releases of Transuranium Elements to the Environment

Although it must be concluded that there is insufficient information at this time to estimate the costs of future accidents, it may be useful to assume some values that place an upper limit on the expected cost of implementing the Guidance. The basic premise underlying this estimate is that the expected annual contribution to new contamination from accidents or other unforeseen events releasing transuranium elements to the environment will not exceed four acres. This establishes an upper limit to the expected costs of implementing this Guidance for cases of future contamination.

It is realistic to expect that accidents of all sizes can occur. Therefore, it is assumed that the size of the area contaminated in a single accident varies, as does the number of accidents occuring in a year's time. The Figure 4.1 represents a possible distribution for the expected total number of acres contaminated in a year's time. The land area requiring remedial action is shown on the horizontal axis and probabilities are shown on the vertical axis. The number of acres that can be contaminated in a year's time ranges from zero upwards. The right hand tail of the function is infinitely long, expressing some probability (although small) that the number of acres contaminated in any single year may be quite large. For example, for the distribution shown here, there is an 8% probability that the land area contaminated in any one year will exceed 10 acres. This distribution has an average value of four acres.

FIGURE



Although the distribution represented in the figure is speculative, it does incorporate the intuitively desirable feature that there is a rather high probability that the total area contaminated by the accidents in a year's time is small, and that the probability declines as the area contaminated increases.

An upper bound estimate of the costs of the remedial action required because of these accidents is derived by assuming that the concentration of transuranium elements is sufficiently high that all surface soils must be removed and disposed of in Federal repositories. Assuming the costs of doing this are equal to the average for the cost of remedial action on the sites investigated by DOE, the average cost of remedial action would be $454,000/acre (Table 4.4), and the expected annual cost of remedial action would be four times $454,000 or $1,816,000.

In using per acre costs based on the DOE analysis, it is assumed that the areas contaminated are diversified in that they contain a variety of land uses, and may contain residential and commercial areas, as well as agricultural and wooded areas. The six large areas in which these averages are based provide sufficient diversity so that the per acre costs are considered to be representative of the types of lands that may be impacted in the case of a future accident.

If the assumptions underlying the per acre cost estimate are changed by assuming that the concentration of transuranium in the soil is low enough that plowing is adequate treatment for all open areas, the DOE estimates show that the unit costs of treatment would be reduced to $59,000/acre, and the expected annual cost would be reduced to $236,000.

These values establish the range $236,000 to $1,816,000 for the expected annual cost of implementing this Guidance in the event of future accidents.

In cases where the level of contamination is sufficiently high that shallow plowing is not adequate to meet the recommended Guidance, alternatives other than storage in Federal repositories (i.e. deep plowing, on-site storage or off-site storage in state reportories) may be considered. In those cases where these methods prove to be adequate, the estimated costs of remedial action are expected to fall somewhere within the range of costs established here.

There is, however, evidence that the low end of this range is itself high. This is because the low estimate of the unit costs of implementation (from Table 4.4) was for the case where all open lands were plowed, but where the surface soils from areas that could not be plowed were removed and transported to Federal repositories.

Comparison of the costs of storage in Federal repositories with the costs of storage in state repositories or storage on-site (Table 4.3) reveals that substantantial savings can be realized when the contamination level is low enough that these types of remedial action can be used. Therefore, the low end of this range could probably be lowered, at least to some extent.

The range of costs established here is based on an average annual contamination of four acres. Historical evidence indicates that this value is probably high. The United States has had over 30 years of experience with activities involving the use of transuranium elements. These activities have been carried out at a large number of locations. Nevertheless, problems have been identified at only the four sites discussed in Section 4.1. As discussed there, it is believed that little or no remedial action will be required to bring these sites into compliance with this Guidance. Even though activties involving the handling of transuranium elements are expected to increase in the future, past history, and increased awareness of the danger from the release of these elements to the environment, gives reason to believe that the annual expectation of four acres of new contamination assumed here may be high.

In summary, the annual costs of remedial action in the event of future releases of transuranium elements to the environment is expected to range from $236,000 to $1,816,000. Nevertheless, there is reason to believe that this range may be high, and that future costs will be lower than estimated.

5. GUIDANCE IMPLEMENTATION

5.1 Introduction

Implementation of the Guidance recommendations involves consideration of all transuranium element environmental contamination and pathways that could result in radiation doses to persons in the general population. Such a consideration includes a determination of the level and extent of existing contamination and the projections of actual or potential doses to a critical segment of the exposed population. This requires an evaluation of the site, a projection of the radiation dose rates via all applicable pathways to determine whether Guidance values are exceeded, and initiation of remedial actions where indicated.

Implementation of the Guidance recommendations is the responsibility of those agencies having regulatory and administrative responsibilities for the site in question and/or the materials in use at a site. A reasonable evaluation of a contaminated site should include a description of the site and environmental measurements of contamination levels in environmental media, in sufficient detail to convey adequate information to the general public. Environmental pathway and dosimetry models used to estimate radiation doses to persons should be described to permit evaluation of the procedures used. If projected dose rates are greater than the recommendations, protective or remedial actions should be performed such that Guidance values are not exceeded and will not be exceeded in the foreseeable future.

In the context of this Guidance, the objective of environmental sampling and analysis is to derive information for the purpose of estimating dose rates to pulmonary lung and to bone of exposed individuals. These dose estimates are derived on the basis of models which consider the various pathways by which transuranium elements in the environment may interact with people and produce exposure to radiation. Such models describe the characteristics of transuranium elements in the environment, the manner in which they may be transported through the air or through food pathways, modes of interaction with man (including inhalation or ingestion) and, finally, factors related to the radiation energy deposition in organs and tissues. In general, dose estimates are best derived from data acquired from measurements in the dose pathway as close as possible to the point where transuranium elements interact with people.

Three general procedures can be used to judge compliance with the Guidance recommendations. These procedures, which are described in more detail in the following sections, may be used for the entire site or for portions of the site as appropriate:

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a. dose rates can be calculated, using the appropriate dosimetry models, from measurements of the concentration of the transuranium elements in air, food, and water at the point of inhalation and/or ingestion by persons. This is the most direct and preferred method.

b. soil concentration levels of the transuranium elements can be compared to a "screening level" for soil, defined as that level below which the concentration of the transuranium elements is not likely to lead to dose rates in excess of guidance recommendations.

c. dose rates can be calculated from the soil contamination levels of the transuranium elements using site-specific parameters for transport models and the appropriate dosimetry models.

5.2 Implementation of Guidance by Estimating Dose Rates to Lung and Bone

Federal agencies may show compliance for a specific site, or for sub-areas of a specific site, by certifying that Guidance values for dose rates to the lung and bone of members of the critical segment of the exposed popoulation are not being exceeded. The most direct method is to measure transuranium element concentrations in environmental media such as air, food, and water at the point of interaction with people and then to calculate the potential radiation dose rates using the appropriate dose conversion factors and dose model parameters. When this procedure is used, adequate documentation should be provided to demonstrate how dose rates are calculated. The Agency favors the use of realistic environmental measurements and realistic model input parameters; conservative parameters should only be used to the extent necessary to compensate for uncertainties.

In certain cases, compliance with the Guidance recommendations may be achieved by restricted occupancy of a site, or portions of a site. Time restrictions for occupancy, or other use limitations, may be established to limit the exposure of a critical segment of the population. Such occupancy or use restrictions should be applied only if remedial actions sufficient to permit unrestricted access are either impossible or economically prohibitive.

5.2.1 Dose Rate to the Lung

Lung dose rates are calculated using appropriate dosimetry models, which require knowledge of the annual average transuranium element concentration in air, aerosol particle size distribution, and solubility class of the specific radionuclides present. Apparatus and procedures for the sampling and analysis of particulates in air are available, but the accuracy and precision of measurements must be verified prior to implementation of the guidance.

Judgment should be exercised in the design of an air sampling program to ensure that air concentration levels are representive of actual exposure conditions. Environmental measurements of airborne particulates which bias the dose estimates by the collection of only certain particle size ranges should be avoided, or a suitable correction should be made. It is preferable that the particle size distribution be experimentally measured for a specific site. Reasonable values can be assumed based on analogies with similar sites when projected lung dose rates are small compared to the Guidance level. The solubility class of an aerosol can usually be determined from the history of the contaminating event and the subsequent environmental weathering mechanisms. Dose conversion factors for lung dose rates that the Agency believes to be reasonable for the purpose of implementation of the Guidance were presented in Annex III.

A derived air concentration "screening level" which if not exceeded indicates with high probability that the guidance recommendations will not be exceeded, may be substituted for a site-specific air concentration limit. The agency suggests that such a derived air concentration "screening level" be based on an activity median aerodynamic particle diameter (AMAD) not to exceed 0.1 um, which is substantially smaller than observed values at all sites where transuranium element contamination presently exists. The calculated limiting concentration for this procedure would be about 1 fCi/m^3 of alpha emitting transuranium nuclides, for air samples averaged over a period of one year or more. Air concentrations above this value do not necessarily mean that the Guidance recommendations may be exceeded, but rather this dictates that a more thorough evaluation of existing conditions should be made.

Elevated levels of transuranium elements in air indicate that these elements may be found in nearby soils. When these levels approach that of the Guidance recommendation, implementation should include a characterization of the environmental source term, to provide a means of judgment with respect to the potential for future exposure levels and the practicality of remedial measures.

5.2.2 Dose Rate to the Bone

Bone dose rates are calculated with appropriate dosimetry models using a knowledge of the average amounts of transuranium elements that are ingested in a year, their chemical state at the time of ingestion, and the proper dose conversion factor. Inhalation of transuranium elements, especially in soluble forms, can also lead to radiation doses to bone and should be considered where appropriate.

Sampling and measurements of transuranium elements in food and water at the point of human consumption is the most direct and preferred procedure for determining the annual average ingested amount of these elements. Alternatively, the amounts of ingested radionuclides may be estimated using environmental pathways models. The chemical state at the time of ingestion is inferred from the medium in which the transuranium elements are incorporated. In particular, transuranium elements which are incorporated into biological tissue should be considered as "organically complexed" and require a special dose conversion factor. Dose conversion factors that the Agency believes appropriate for the implementation of this Guidance with respect to bone dose rates were given in Annex III.

Suitable sampling and analytical procedures are available for the analysis of the transuranium elements in food and water. As with the inhalation pathway, elevated levels of plutonium and the transuranium elements in food or water indicate that these elements may be found in nearby soil or in sediments. Under such conditions, implementation of the Guidance should include a characterization of the environmental source term, to provide a means of judgment with respect to the potential for future exposure levels and the practicality of remedial measures.

5.3 Implementation of Guidance by Use of a Soil "Screening Level"

Federal agencies may show compliance for the total area of a site, or for subareas of a site, by certifying that such areas have transuranium element soil concentration levels less than a "screening level" value of 0.2 uCi/m^2. The "screening level" is a total transuranium element soil concentration level in the top 1 cm of soil such that, in the Agency's opinion, dose rates will not exceed Guidance recommendations under the vast majority of land use conditions. When this implementation mechanism is used, all lands subject to unrestricted use must meet the screening level criteria. Because of present uncertainties in the amount of plant uptake for the more soluble transuranium nuclides, such as americium and curium, and the resultant possibility of larger doses via the ingestion pathway than calculated, the "screening level" concept may not be applicable when the soils of a contaminated area contain these nuclides in amounts greater than 20-25% of the total activity. Lands with concentration levels less than the "screening level" are judged to be suitable for all normal activities including residential and agricultural uses. The use of this "screening level" is intended to reduce the land areas requiring extensive evaluation and to minimize the number of measurements needed.

If land areas have transuranium element levels greater than the "screening level," it should not be presumed that Guidance values are necessarily exceeded, because conservative assumptions were used in the derivation. Additional site specific evaluations of potential dose rates to lung and bone (Section 4) should be made before remedial actions are initiated.

Inherent in the application of the screening level is the assumption that soil contamination by the transuranium elements will cause radiation exposure through pathways such as the inhalation of resuspended soil, the ingestion of foodstuffs grown on the soil, the ingestion of soil by children, and the ingestion of drinking water contaminated by soil runoff. In all cases the cumulative doses to the critical segment of the population must be considered, with the admonition that the accumulated doses from all pathways should not exceed those recommended in this Guidance.

5.4 Implementation of Guidance by Means of Soil Data Using Site-Specific Parameters

Federal agencies may show compliance with this guidance for a specific site, or for subareas of a specific site, by means of soil measurements and by using pathway and dosimetry models with parameters determined for the specific site to certify that the resulting dose rates do not exceed Guidance values. This approach differs from the use of a soil "screening level" because parameters such as the resuspension factor are determined for a specific site. It is expected that use of site-specific parameters will show that soil contamination levels higher than the suggested "screening level" may correspond to organ doses well below Guidance levels. Implementation by site-specific parameters is appropriate where land areas have transuranium element levels greater than the "screening level" and further evaluation is necessary to determine whether or not guidance dose limits are being exceeded.

The air concentration where people are located generally can be correlated with the adjacent soil concentration by use of a resuspension factor, and can be used to estimate the inhalation dose rate. The site-specific resuspension factor may be either measured directly or calculated from other data. Direct experimental determinations are often difficult to make and not always reproducible. Therefore, calculational techniques are sometimes preferred although their correlation with measured values is subject to considerable uncertainty. The agency staff has developed a method, based on the concept of air mass loading, which may be useful for this purpose(see Annex II). An "effective" resuspension factor is derived, defined as the resuspension factor derived from the air mass loading for the given location and modified by a "distribution factor" which takes into account the generally observed nonuniform distribution of the activity with size of particles in calculating the amount of transuranium element activity in the inhalable fraction of the resuspended material. The "distribution factor" is a theoretically derived parameter, and its correlation to actually observed situations has not yet been established. The resuspension factor derived in this manner is applicable only to extremely large areas sources, and must be further corrected for the dilution by uncontaminated materials when used for small contaminated areas.

The ingestion pathway must be evaluated separately, using data applicable to the specific site in terms of type of crops, plant uptake parameters, and pathway to a critical segment of the population. The more unusual transfer mechanisms to people, such as the ingestion of dirt by children and the contamination of drinking water sources, may also need to be examined if shown to be of importance.

5.5 Sampling and Analysis Methods

Choice of Methods

The choice of suitable methods for sampling and analysis is the reponsibility of the Agency implementing the Guidance. The implementing Agency should demonstrate that the proposed methods have the necessary sensitivity, accuracy, and precision. A description of the apparatus and techniques used to collect the samples, the procedures for preparing the samples for analysis, and the method used for radiochemical analysis should be included.

Air Sampling

When air sampling is chosen as the principal method of implementing the guidance, continuous monitoring should be performed at locations indicative of potential doses to persons in the general population. Aerosol collection efficiencies as a function of particle size and other appropriate parameters must be reported for the instruments and placements used. Results must be given in terms of an annual average air concentration of transuranium elements at the specified site.

Food Sampling

When foods are grown in contaminated soils, and the ingestion pathway may represent a hazard to persons in a critical segment of the population, representative samples should be obtained for analysis and evaluation. Results should be reported in terms of activity per unit of wet or dry weight, as appropriate, for specific food products and for typical "market basket" averages for an individual.

Drinking Water Sampling

When soil or sediment analyses indicate the potential for the presence of transuranium element contamination in drinking water supplies, periodic monitoring should be performed. Results should be reported in terms of activity per unit volume for both raw and finished drinking water.

Soil Sampling

When soil sampling is chosen as either the principal or ancillary method of implementing the Guidance, statistically valid procedures appropriate to the objective should be used to characterize the entire area known or suspected to be contaminated. When soil measurements are made to evaluate the inhalation pathway, emphasis should be on obtaining representative samples of surface soils subject to resuspension and transport. In order to achieve a degree of uniformity in application, the Agency recommends that soil samples be taken to a depth of one centimeter and include all soil particles less than two millimeters in size. Several individual samples may be composited for a single measurement. At some sampling points it may not be possible to collect samples to a depth of one centimeter e.g., very stony soil or a thick grassy area). In such cases, other means must be found to obtain representative samples.

For site-specific evaluations of resuspension parameters, it may be necessary to determine the fraction of the total activity associated with ranges of soil particle sizes (distribution factor). Standard liquid or air sedimentation and separation techniques may be used for this purpose. In general, soil characteristics should be altered as little as possible in the collection and preparation of the soil sample and care should be taken to choose a method which does not cause the breaking up of soil aggregates that were present when the sample was taken.

Radiochemical analysis techniques for the determination of transuranium elements in soils are available and have been published. These differ primarily in the method used to solubilize the plutonium in the sample. Acid leaching, acid dissolution, and fusion are most commonly used. The fusion method is considered to be applicable to a wider variety of soils than the other two methods.

Alternative collection, separation, and analysis methods may be used but must be adequately justified in terms of technical validity and relationship of results obtained by the recommended method.

Statistical Criteria

The characterization of any large area in a cost-effective manner requires that the sample locations be carefully determined in order to optimize the information obtained. Statistical methods are available to permit design of experiments to obtain results with the accuracy and precision desired.

When planning a soil survey it is advisable to divide the total area under investigation into units at the very begining of the survey rather than to collect samples more or less haphazardly. Then samples taken to determine the acceptability of the land by comparison of measured concentration levels to the screening level may be collected from sampling units in accordance with a sampling plan. If it is later decided that more sampling is necessary, no change in the sampling plan is necessary, and the location for additional samples will have already been determined.

The number of samples to take within a sampling unit may be estimated from the specific statistical approach used in the sampling plan. An important factor affecting the number of samples to be taken is the risk of making the wrong decision in deciding whether a sampling unit is acceptable or requires remedial action. To reduce the risk of making the wrong desision, larger numbers of samples must be taken. Judgment must be used to strike a balance between the desirability of making the right decision and the difficulties and expense involved in taking large numbers of samples. An additional factor affecting the number of samples is the variability of the transuranium element concentration within a sampling unit. If detailed information is not available on the variability, a simple approach is to take the same number of samples within each unit. These could be taken on a grid system to ensure that all subareas of the sampling unit are sampled. A disadvantage of this approach is that if the variability is substanially different in units, then the probability of detecting concentration levels requiring remedial action will vary from unit to unit. If estimates of variability are available from past studies, these can be used to help determine the number of samples required within each unit so that the probability of making a correct decision will be the same for all units.

After soil concentration levels have been determined, it must be decided if the area under consideration complies with the Guidance recommendations or whether further evaluation will be needed. The statistical methodology that is used must be such that few assumptions regarding the form of the soil concentration distribution will be necessary to ensure the validity of the statistical test. The method should also ensure reasonably low bounds on the risk of making the wrong decision, and the probability of not accepting an area which meets the guidance, or accepting one which does not, should be small. Acceptance criteria which allow a maximum chance of error of 5-10% are generally considered appropriate.

Considerable variation generally occurs in environmental samples taken even in closely adjacent locations. If one or more samples from any unit exceed the air or soil concentration limits corresponding to the guidance recommendations, a decision must be made on whether the sampling unit is acceptable. Such decision is best based on statistical tests which consider both the magnitude of the deviations from the average and the number of samples which are involved. A number of statistical methods are available for performing such an evaluation, and the choice must be made on the basis of the data available and the results desired.

6. THE DOSE AND RISK TO HEALTH DUE TO THE INHALATION AND INGESTION OF TRANSURANIUM NUCLIDES

6.1 Revised Risk Estimates For Leukemia

Due to a computational error, the leukemia risk estimates published in Annex III of the proposed guides (Pr 77) are too low. While this has little effect on the estimated total risk due to the inhalation of Class Y materials, it does affect the estimated lifetime risk due to ingestion, as well as estimated risk due to the inhalation of class W materials described in section 6.3 below.

Amended risk estimates are given in Table 6.1.1. As before, all risks are based on lifetime exposure to 100,000 persons at the proposed guidance limits: for inhalation, 1 mrad per year to pulmonary tissue and for ingestion, 3 mrad per year to bone tissue in the 70th year.

TABLE 6.1.1

New Leukemia Risks for Lifetime Exposure to Plutonium-239

Estimated Risk	Cancer Deaths per 100,000 Exposed Inhalation - Class Y	Ingestion
Leukemia	1.2	9
New total Ca risk	10	14
Total risk estimated in Annex III	9*	5.6

* Table A3-18

The table above is based on a quality factor of 20 for alpha particle irradiation, as stated in the guidance document. This choice is based on ICRP Report No. 26, referenced in Annex III. More recent information on the leukemia experience of Japanese atomic bomb survivors than was available when Annex III was prepared, indicates that a quality factor of twenty is not unduly conservative for purposes of estimating risk of leukemia from high LET radiations. Risk estimates based on the tissue dose rather than kerma exposure to the Japanese survivors are discussed in Section 6.2 below.

6.2 Estimates of Leukemia Risk Based on Tissue Dose

The leukemia risks for high LET radiation, mainly proton recoils, in the 1972 BEIR Report are based on "tissue kerma in air", i.e., attenuation of the dose by tissues overlying the bone marrow was neglected. Recently, T. Ishimaru, M. Otake, and M. Ichimaru have reviewed the dose response pattern for the Japanese survivors in terms of the calculated dose to bone marrow (Is 77). This was made possible by detailed information on the gamma ray and neutron doses to bone marrow developed by the Oak Ridge National Laboratory subsequent to the BEIR Report (Jo 76). These results indicate that the proton dose to marrow was only 26 percent of the tissue kerma in air, an appreciable difference. Moreover, use of tissue dose for high LET particles allows leukemia risks to be estimated directly (i.e., per unit rad), rather than by means of an arbitrary quality factor based on a number of end points. Except for leukemia, direct calculations of risk per rad were used throughout Annex III to calculate somatic risk. Therefore, use of such a direct approach should make the estimates of leukemia risk more comparable to that for other cancers. It should be noted that the linear energy transfer (LET) for 5 MeV alpha particles from the decay of transuranium nuclides is nearly the same as for one MeV recoil protons.

In their review of risk to Japanese survivors, Ishimaru *et al.* fitted various dose responsive functions to the leukemia incidence data to account for both the gamma-ray and neutron dose. For the gamma-ray dose, linear, parabolic, and quadratic responses were examined in combination with a linear response for the high LET recoil dose. Use of these various models resulted in little difference in the calculated risk for neutrons, 23-28 cases per million rad person years at risk. Although there is no statistically significant difference between these two estimates, the former number, based on a linear response for both neutron and gamma radiation, is utilized below.

Unlike the 1972 BEIR Report, the results cited above on the leukemia risk due to neutrons does not consider children of less than ten years of age as a separate population at risk. Rather, the analysis is based on all ages. This should not be a serious source of bias since the proportions of persons under ten among the Japanese survivors is not too different from that in a stationary population. Moreover, exposures during childhood contribute only two to ten percent of the total number of excess leukemia cases resulting from lifetime exposures to transuranics.

Input parameters for the leukemia risk estimates are listed in Table 6.2.1, the selection of plateau period and duration of the latent period are based on the 1972 BEIR Report (Na 72). The relative risk coefficient is based on the regression results for bone marrow neutron dose given for Model I by Ishimaru *et al.*, (Is 77).

Table 6.2.1

Parameters for Leukemia Risk Estimates
High LET Particle Dose to Bone Marrow

Latent Period (Years)	Plateau Period (Years)	Absolute Risk Death per 10^6 RPY*	Relative Risk % increase in deaths per rad
2	25	23	70%

*Rad x person years at risk

Table 6.2.2 compares the average of relative and absolute risk estimates made with these parameters to those listed in Table 6.1 for plutonium-239 ingestion.

Table 6.2.2

Leukemia Risk for Lifetime Exposure
Per 100,000 Persons - Bone Tissue Limit
3 mrem Per Year in the 70th Year

Basis for Calculation	Estimated Deaths
Quality factor of 20, Table 6.1.1	9
Japanese Survivors, Table 6.2.1	14

6.3 Dose Rates and Estimated Risks Due to Inhaled Class W Compounds

6.3.1 Introduction

The ICRP Task Group Lung Model (Ta 66, In 72) classifies inhaled aerosols into three groups depending on the length of time they are retained in the lung. Class Y compounds are retained for years, Class W for weeks, and Class D for days. The retention times are largely controlled by the solubility of the inhaled material in body fluids. In the technical document (Annex III) for the proposed guidance (Pr 77), it was assumed that respirable materials which persisted in the environment would most likely be insoluble oxides and hydroxides and therefore be Class Y materials. However, there is some evidence from animal experiments that high specific activity plutonium oxides such as $^{238}PuO_2$ are more soluble than the long half life transuranics and should be considered Class W compounds. Moreover, other transuranics, such as americium-241 and curium-244 may in some cases be in a chemical form that leads to Class W behavior. The purpose of this section is to examine the dose due to the inhalation of Class W transuranium aerosols and the estimated risks from such exposures. It should be noted that solubility as a function of size is not considered by the ICRP Task Group Lung Model. In practice, higher solubility for sub-micron aerosols is likely to occur; therefore, the estimated risk due to compounds more soluble than Class Y materials is also of interest for this reason.

6.3.2 Application of the Proposed Guidance to Class W Transuranium Compounds

The proposed guidance places two limitations on the alpha particle dose rate to exposed persons: a maximum dose rate of 1 mrad per year to pulmonary lung tissues and a maximum dose rate of 3 mrad per year to bone tissue after a 70-year (lifetime) exposure. In both cases the alpha energy is averaged over the total tissue mass (Pr 77). Because of their shorter residence time in lung tissues, inhaled Class W transuranics result in a relatively small lung dose compared to that received by other organs due to the translocation and deposition of dissolved material. Therefore, the dose rate to bone tissue becomes limiting, not the dose rate to pulmonary lung.

Table 6.3.1 lists the air concentrations of Class W transuranium radionuclides that result in an average bone alpha dose of 3 mrad per year after 70 years of exposure. The potential risks due to inhalation of Class W transuranics are not confined to bone cancer but include leukemia and cancer of the liver and lung as well as genetic effects, see Section 6.3.4 below.

TABLE 6.3.1

Aerosol Concentrations in fCi/m^3 Producing a 3 mrad Annual Skeletal Dose Rate in the 70th Year Following Lifetime Inhalation by Reference Man - Class W Solubility

Size (AMAD)	$^{238}_{94}\mathrm{Pu}$	$^{239}_{94}\mathrm{Pu}$	$^{241}_{94}\mathrm{Pu}$*	$^{241}_{95}\mathrm{Am}$	$^{244}_{96}\mathrm{Cm}$
0.05	5.7	4.8	200	4.7	11
0.10	6.4	5.3	220	5.3	12
0.30	7.6	6.3	260	6.3	14
0.50	7.8	6.5	270	6.4	15
1.0	7.8	6.5	270	6.4	15
2.0	7.2	6.0	250	6.0	14
3.0	6.7	5.6	240	5.5	13
5.0	6.4	5.4	230	5.3	12

*Only alpha dose rate due to the Am-241 daughter is considered in assessing limit

For most transuranic materials (the exception is Plutonium-241) the limiting concentration in air of a Class W material is greater than that for a Class Y material containing the same radionuclide. This difference is as much as a factor of five or more for the smallest particle sizes, considered in Table 6.3.1, c.f. Table 6.3.1 with Table A-3-4 in Annex III(3). For 1 micron AMAD particles the limiting concentration of Class W compounds is about 3 times greater than for Y compounds. For this reason, there must be reasonable assurance that the inhaled material is in the form of a Class W compound before Table 6.3.1 is used to establish compliance with the proposed guides. When a mixture of Class Y and W compounds are inhaled, compliance should be based on the limiting concentration for Class Y materials unless the proportion of each type of pollutant has been fully established. Plutonium-241 is an obvious exception since the limiting concentration is up to 8 times less for a Class W than for a Class Y material.

6.3.3 Alpha Particle Dose Rates from Inhaled W Aerosols

The annual dose rates following 70 years of inhalation exposure to several transuranium radionuclides in the W form are listed in Table 6.3.2 for 1 micron (AMAD) particles. More than 99 percent of the equilibrium dose rate to pulmonary lung tissue is achieved after five years of exposure. For other organs the dose rate increases with the duration of exposure. It is recognized that lifetime exposure to a constant concentration of curium-244 aerosols is unlikely because of its relatively short half life (17 years).

TABLE 6.3.2

Annual Dose Rates to Various Organs of Reference-Man Following Chronic Lifetime Exposure to Class W Transuranium Aerosols Concentration 1 fCi/m^3; Particle Size 1 micron (AMAD)

	Equilb. Dose Rate (microrad/y)		Dose rate in the 70th yr (microrad/y)		
Radionuclide	Pulmonary Lung	Tracheobronchial Lung	Bone	Liver	Bone Marrow
Pu-238	41	16	390	810	340
Pu-239	39	15	460	930	400
Pu-241	0.04	0.01	10	20	9
Am-241	41	15	470	960	410
Cm-244	44	17	200	460	180

Effective biological half lives and removal pathways for lung deposited Class W compounds are described quantitatively in (Su 77), along with the description of the analytical techniques used in the preparation of Table 6.3.2. As was the case for Class Y materials, eight particle sizes (AMAD) were considered in these calculations. The variation of dose rate with particle size of Class W particles is shown in Table 6.3.3. Unlike the case of Class Y particles, a broad minimum dose rate to liver and bone is observed for aerosols of between 0.3 and 1 micron (AMAD). The variation in pulmonary dose with particle size is the same as for Class Y compounds.

TABLE 6.3.3

Variation with Particle Size of the Dose Rate to Pulmonary Lung, Bone and Liver for Inhaled Class W Aerosols (Lifetime Inhalation at a Constant Concentration)

Particle Size AMAD (Microns)	Equilibrium Lung Dose Rate Ratios*	Dose Rate Ratios* for Bone and Liver in the 70th Year
0.05	2.6	1.4
0.10	2.2	1.2
0.30	1.6	1.0
0.50	1.4	1.0
1.00	1.0	1.0
2.00	0.7	1.1
3.00	0.6	1.2
5.00	0.5	1.2

*Normalized to 1 micron (AMAD)

6.3.4 Health Risk Estimates for Class W Transuranics

The inhalation of Class W compounds results in both somatic and genetic risks. Although the limiting dose rate for inhaled Class W compounds is in terms of the dose to bone, the dose to lung tissue is not negligible. The estimated risk of lung cancer is about the same as the estimated risk of leukemia, liver or bone cancer. The genetic risk for inhaled Class W transuranium materials is larger than for inhaled Class Y aerosols, being nearly the same as the genetic risk for ingestion listed in Annex III (Pr 77).

The methodology for estimating somatic and genetic risks due to the inhalation of transuranics is discussed in Annex III (Pr 77). Like the case for transuranium ingestion, where the dose rate limitation for bone tissue is also 3 mrad per year, the 30-year gonadal dose for most inhaled Class W transuranium compounds is about 10-12 mrad, i.e., calculations of 30-year gonadal dose for Class W yielded results identical to those listed in Table A3-15 of Annex III (Pr 77).

Therefore, the estimated genetic risks for Class W inhalation are the same as listed in Table A3-16 (Pr 77) for the ingestion pathway.

Estimated somatic (cancer) risk following inhalation of Class W are listed in Table 6.3.4 below. The assumptions made in the calculations of these risk estimates are the same as made for Y compounds in Annex III except that a quality factor of 20 was used for leukemogenesis.

TABLE 6.3.4

Estimated Risk of Cancer Due to a Lifetime Inhalation Pattern That Results in a 3 Mrad Per Year Alpha Particle Dose Rate to Bone in the 70th Year - Number of Deaths per 100,000 Persons

Class W Aerosols

Cause of Early Death	Radionuclide				
	Pu-238	Pu-239	Pu-241	Am-241	Cm-244
Lung cancer	2.6	2.1	0.11	2.1	5.4
Bone Cancer	2.6	2.4	1.9	2.5	3.4
Liver Cancer	2.2	1.9	1.4	1.9	3.1
Leukemia	9.2	8.8	7.6	8.8	10.8
TOTAL	17	15	11	15	23

6.4 Transfer of Transuranium Material to Blood From the GI Tract

In the course of reviewing the literature on transuranium elements while preparing "Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment", the staff was concerned about using truly appropriate gut transfer factors for the transuranium isotopes. While ICRP Report #19 recommends a gut transfer factor of 1 part per 10^6 for "relatively insoluble material, such as PuO_2", transfer fractions of the order of 10^{-2} to 10^{-4} are not uncommon in more contemporary reports (Su 75, Su76, Fi 76, Br 75). In view of these reports of higher gut transfer factors, the staff took advantage of an ERDA offer of aid from their contract laboratories. The letter containing EPA proposed gut transfer factors circulated to ERDA investigators considered knowledgeable in this field is reproduced below.

13 DEC 1976

Dr. William J. Bair
Director, Life Sciences Program
Pacific Northwest Laboratories
Battelle Memorial Institute
Richland, Washington

Dear Bill:

In the hope of trying to reach accord with ERDA on the dosimetric parameters used by EPA in developing guidance for plutonium in soils, we are asking several ERDA investigators for relevant comments.

Neal Nelson has prepared a table of provisional gut transfer fractions for transuranic isotopes, enclosed. The data is derived primarily from ERDA's BNWL presentation at the EPA hearings in Washington (WASH-1539) and from the 1975 BNWL Annual Report, BNWL-2000-PTI (Sullivan and Crosby). Since these reports reflect, for the most part, observations on rats, some consideration was also given to Battelle data on swine (BNWL-280) and Buldakov, et al.'s data on dogs.*

Your comments on whether these gut transfer factors seem reasonable or not, and any modifications you would suggest, based on your own interpretation of the Battelle or other data, would be appreciated.

---

*L. A. Buldakov, E. R. Lyubchanskii, Yu. I. Moskalev and A. P. Nitatov, Problems of Plutonium Toxicology, LF-tr-41, 1970.

If possible, we would like your comments before Christmas as we are trying to complete a new draft, not a redraft, on dose and effects. Since the mails are bad, perhaps you would phone Neal or me (202-755-3852) after you have reflected on the proposed numbers.

Sincerely yours,

W. H. Ellett, Ph.D.
Chief, Bioeffects Analysis Branch
Criteria & Standards Division (AW-460)
Office of Radiation Programs

Enclosure

cc: Dr. Chester Richmond, Oak Ridge National Laboratory
Dr. Roy Thompson, Battelle Northwest Laboratory
Dr. John Marshall, Argonne National Laboratory

AW-460/NSNelson/mlb 12/10/76 WSME 629, ext 53852

Provisional Gut Transfer Fractions for Transuranic Elements

Isotope	Infant (0-1 yr)	Child (> 1-9 yr)	Adult (≥ 10 yr)
Np^{+5} soluble	7×10^{-2}	10^{-2}	10^{-2}
oxide	---	---	---
biologically incorporated	---	10^{-3}	10^{-3}
$^{238}Pu^{+4}$ soluble	2×10^{-2}	3×10^{-4}	3×10^{-4}
oxide	5×10^{-4}	2×10^{-4}	2×10^{-4}
biologically incorporated	---	3×10^{-3}	3×10^{-3}
$^{239}Pu^{+4}$ soluble	4×10^{-3}	2×10^{-4}	2×10^{-4}
oxide	2×10^{-4}	10^{-6}	10^{-6}
biologically incorporated	---	---	---
Am^{+3} soluble	9×10^{-2}	5×10^{-4}	5×10^{-4}
oxide	5×10^{-3}	10^{-4}	10^{-4}
biologically incorporated	---	---	---
Cm^{+3} soluble	6×10^{-2}	10^{-3}	10^{-3}
oxide	10^{-2}	10^{-4}	10^{-4}
biologically incorporated	---	---	---
Bk, Cf, Es soluble	4×10^{-2}	5×10^{-4}	5×10^{-4}
oxide	---	---	---
biologically incorporated	---	---	---

[Estimates based on Battelle rat and pig data and Russian dog data.]

Scientists at Battelle Pacific Northwest Laboratories considered the question in some detail and simplified the age specific table of gut transfer factors proposed in the EPA letter. Their response is reprinted below. It acknowledges both the uncertainty and conservatism in these estimates, a conservatism necessitated by the extrapolations from animals to man.

The EPA staff used the estimates provided by BPNL scientists as prudent values for protection of public health in their development of the Guidance for Transuranium Elements.

Responses from other ERDA investigators were of a non-numerical character and not directly applicable to the problem.

Battelle
Pacific Northwest Laboratories
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Richland, Washington 99352
Telephone (509) 946-2421
Telex [illegible]

February 1, 1977

Dr. W. H. Ellett
Dr. N. S. Nelson
Criteria and Standards Division - ORP
Environmental Protection Agency
Waterside Mall - 629E
4th & M Streets SW
Washington, D.C. 20460

Dear Bill and Neal:

We have had extensive discussions with several scientists in the Biology and Ecosystems Departments concerning your need for gut transfer numbers. As you are well aware, this is an area of current active investigation and everyone would rather have a few more years to get better answers. But we recognize your problem and will attempt in this letter to give our best advice, emphasizing that it is an interim appraisal, almost certainly erring on the conservative side, and, of course, subject to future revision.

We will make no attempt in this letter to review the data. You are as aware of most of this data as we are--as evidenced by the extensive compilation of numbers enclosed in your recent letter. One of our objectives has been to reduce the complexity of that table, since we feel that it implies a great deal more confidence in small differences than we are entitled to have. We are all aware of the many uncertainties involved in the measurement of these numbers and in their extrapolation from animals to man.

The numbers we would recommend for all transuranics are the following, expressed as fraction absorbed to blood:

Child and Adult ($\geq$ 1 year): 10^{-3}

except: 10^{-4} for $^{239}PuO_2$, 5×10^{-3} for biologically incorporated transur

Infant (< 1 year): 10^{-1}

except: 10^{-2} for $^{239}PuO_2$

This amounts to choosing a single basic value of 10^{-3}, to which we make 3 exceptions a factor of 10 decrease for $^{239}PuO_2$, a factor of 5 increase for biological incorporation, and a factor of 100 increase for the infant to age 1 year.

Our basic factor of 10^{-3} is conservative, but this seems justified in view of the uncertainty involved in extrapolation to the human. It is undoubtedly more conservative for plutonium than for the transplutonium elements, and not conservative for neptunium, but this seems reasonable in view of the relative significance of these various elements as possible environmental contaminants.

Because of the abundance of data showing a much lower absorption for $^{239}PuO_2$, and because of the importance of this compound, an exception seemed justified. A figure of 10^{-5} might well be justified from animal data, but again we felt that in view of the uncertainties in extrapolation to man, conservatism was in order.

The factor of 5 for biological incorporation is based on very limited, and not always consistent, results from experiments in progress, in which rats and guinea pigs were fed alfalfa that contained biologically incorporated plutonium. We may have a better basis for this number within a few months.

Without doubt the greatest uncertainty attaches to the number chosen for the infant, and to the time period assigned to infancy. The factor of 100 seems to be a maximum enhancement factor, based on the data available. There is a decrease in this enhanced absorption with age, but no clear basis for extrapolating this decrease to man. Depending on your assumed theory for explaining the enhanced absorption you can argue for a period of a few days, or for a much longer period. We feel that assuming a high enhancement value of 100, without decrease over the first year of life, is a conservative approach. Rather than listing an absorption factor of 10^{-1}, for which the evidence is so indirect, we would prefer to use the adult factor in all calculations and then apply a lifetime "correction factor" of 2 to account for possibly enhanced absorption during infancy, thus stating no specific increase and no specific period during which it applies.

We have applied the factor of 10 reduction for $^{239}PuO_2$ to the infant because of the substantial amount of data showing that transuranic oxides are less well absorbed by very young animals than are other compound forms.

We have not applied the biological incorporation factor to the infant, primarily because it would involve multiplying three conservatively chosen numbers to arrive at a prediction of 50% absorption, which seems quite unreasonable. On more scientific grounds, one can argue that the mechanisms for enhanced absorption due to infancy and due to biological incorporation are most likely totally unrelated and therefore not multiplicative in their application.

We hope that this effort has been helpful. There are no easy answers. We will keep you informed of any new developments in our research in this area, and would be glad to respond to any further questions that you might have.

Sincerely,

Bill

W. J. Bair, Ph.D.
Manager
Environmental & Safety
Research Program

Roy

R. C. Thompson, Ph.D.
Senior Staff Scientist
Biology Department

RCT:WJB:ms

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7. Rocky Flats Facility/Technical Assessment Document

7.1. Introduction

The purpose of this report is to present an analysis of the potential hazards to individuals in the general population as a result of present levels of the transuranium elements existing in the environs of the DOE Rocky Flats Plant. The various pathways by which exposures might occur under present and projected land usages are examined and interpreted in light of EPA's proposed guidelines for exposures to the transuranium elements.

7.2 Inhalation Pathway

7.2.1 Ambient Air Concentrations

Under normal operating conditions, minute quantities of plutonium and other radionuclides are released per year to the atmosphere from the Rocky Flats Plant. These releases are of small magnitude and originate from the plant's ventilation and filtration system. In addition to continuously monitoring the effluent air from production and research facilities, the Rocky Flats facility maintains a system of high-volume ambient air samplers within the plant boundary, at off-site locations in the immediate vicinity of the plant, and in several nearby communities. Altogether the system comprises 21 air samplers operating continuously within and on the perimeter of the Rocky Flats security area, and another 25 samplers located at various distances and directions from the plant. The data from this network are reported on a monthly basis to the Rocky Flats Area Office of DOE, the Division of Occupational and Radiological

Health of the Colorado Department of Health, the Denver Regional Office of the EPA, the Health Departments of Boulder and Jefferson Counties, and city officials in several communities near the plant.

In addition to the surveillance network maintained by the Rocky Flats Plant, the Health and Safety Laboratory (HASL) of DOE has conducted a program of continuous air sampling for plutonium at the Plant since June 1970 in response to the discovery of elevated levels of plutonium found in soils at location which were then off-site. The HASL network consists of four sampling locations (Figure 7.1), three of which are downwind (east) from the original location of the oil drum storage site and the fourth air sampler is located off-site and upwind from the Rocky Flats Plant (2). Air concentration data in attocuries of Pu-239 per cubic meter of air (aCi/m^3)*, as reported by this network on a monthly basis from June 1970 to March 1976, are given in Table 7.1. A significant downward trend with time can be seen in the level of plutonium in air at the stations downwind from the plant. It has been suggested by HASL that this downward trend is attributable to the weathering of the contaminated soil in the on-site vicinity of the original oil drum storage site. This weathering may be due to the movement of the plutonium from the surface down into the soil, as well as changes in the characteristics of the plutonium remaining on the surface. In addition to showing a decrease with time, the data indicate a decrease in concentration with increasing distance downwind from the site of the original spill area. Based upon air and soil sampling, as well as the direction of the prevailing winds around Rocky Flats, HASL concluded in 1972 (3)

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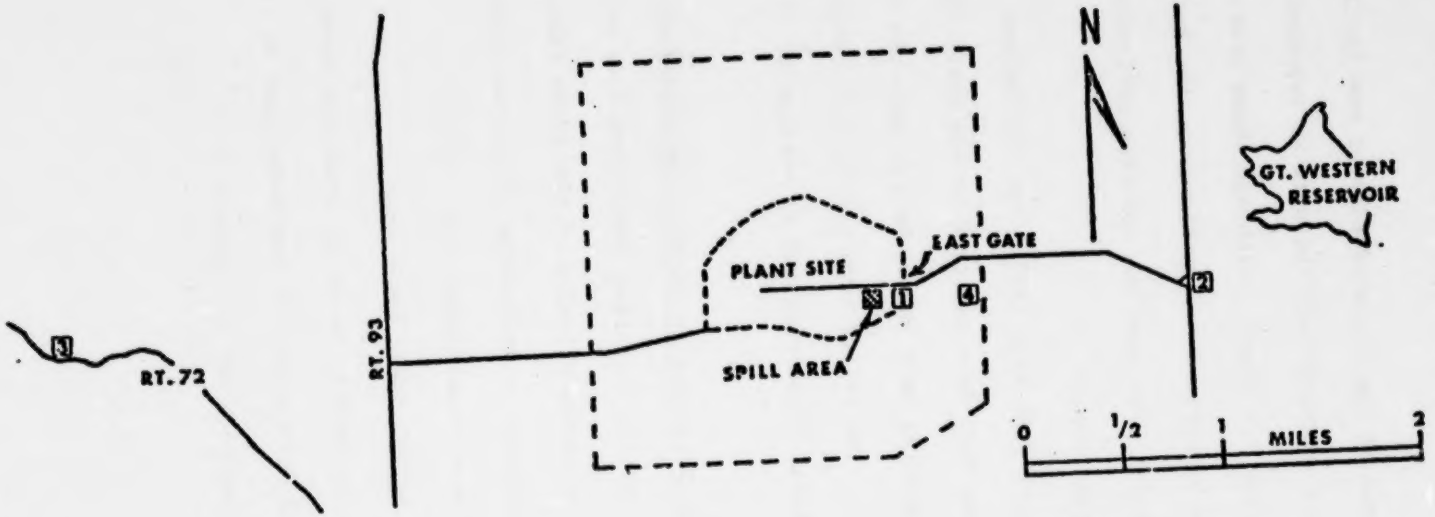
*1 attocurie = 10^{-18} curie


RT. 72
3
RT. 93
PLANT SITE
SPILL AREA
1
4
EAST GATE
N
2
GT. WESTERN RESERVOIR
0
1/2
1
MILES
2

MAP OF ROCKY FLATS PLANT AND VICINITY
INDICATING CONTINUOUS AIR SAMPLING SITES

FIGURE 7.1

that the original spill area was the primary source of plutonium in the Rocky Flats environment.

Levels of airborne plutonium at the downwind edge of the facility's buffer zone (Indiana Street) are approximately the same as reported for the monitoring station upwind from the plant. Although these levels are about twice those expected from background radioactivity in the Rocky Flats area, the effect of the spill area upon the off-site environment has been much reduced from earlier levels.

Comparison of the most recent HASL data (1976) for the Indiana Street location (site 2) with the 1975 data reported by the Rocky Flats Plant (Table 7.2) for the same general area shows the two networks to agree within a factor of about 2. The values reported by HASL range between 12 to 23 aCi/m^3, while Rocky Flats reported an average of 37 aCi/m^3.

7.2.2 Calculation of Inhalation Doses Due to On-Site Contamination

An assessment has been made of the potential inhalation dose which could be received by individuals residing off-site of the Rocky Flats Plant. In carrying out this assessment, a deliberate effort has been made to choose assumptions which are conservative, i.e., likely to result in an overestimate of the actual dose. These are:

a) Inhaled plutonium is considered to be in an insoluble form. (Chemical solubility of an aerosol determines its residence time in the lung, with insoluble compounds being retained the longest.)

b) The plutonium aerosol is assumed to have a lognormal distribution with an activity median aerodynamic diameter (AMAD) of 1 micrometer. (According to the ICRP (4) this implies that approximately 25% of the aerosol will be deposited in the pulmonary compartment of the lung. HASL (5) has reported 25% of the airborne activity being in the respirable range around Rocky Flats, while Sehmel (6) has reported a 20% respirable fraction).

c) The individual is considered to be exposed continuously for 70 years at the currently observed air concentration. (No further reduction in airborne activity as a result of weathering or remedial actions is assumed.)

d) All plutonium measured was assumed to originate from on-site, with no correction being made for ambient background levels of plutonium.

The PAID code developed by EPA (7) was used to calculate the annual dose rate. This computer code is based upon the ICRP Task Group Lung Model (4) and calculates dose rates to various body organs as a consequence of inhaling transuranic material. Tables 7.3 and 7.4 have been generated by the PAID code and relate years of exposure to the resultant dose rate for various organs. Values in the tables are normalized to an aerosol concentration of 1.0 femtocurie per cubic meter of air (fCi/m^3)* with a 1 μm AMAD.

Indiana Street Location

Indiana Street is the nearest location to the Rocky Flats Plant where an individual in the general population could be exposed as a result of transuranium contamination originating from the Plant. This location is in the downwind direction of the prevailing winds that blow across the Rocky Flats Plant and, therefore, would represent a worst case for offsite exposure.

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* 1 femtocurie $=10^{-15}$ curie.

From Figure 7.2 it can be seen that stations S-35, S-36, S-37, S-38, and S-39 are located along Indiana Street. Station S-37 reported the highest annual average for 1975 of 0.056 fCi/m^3 (Table 7.2). Assuming this level to continue for the next 70 years, the 70th year dose rates to lung and bone can be calculated.

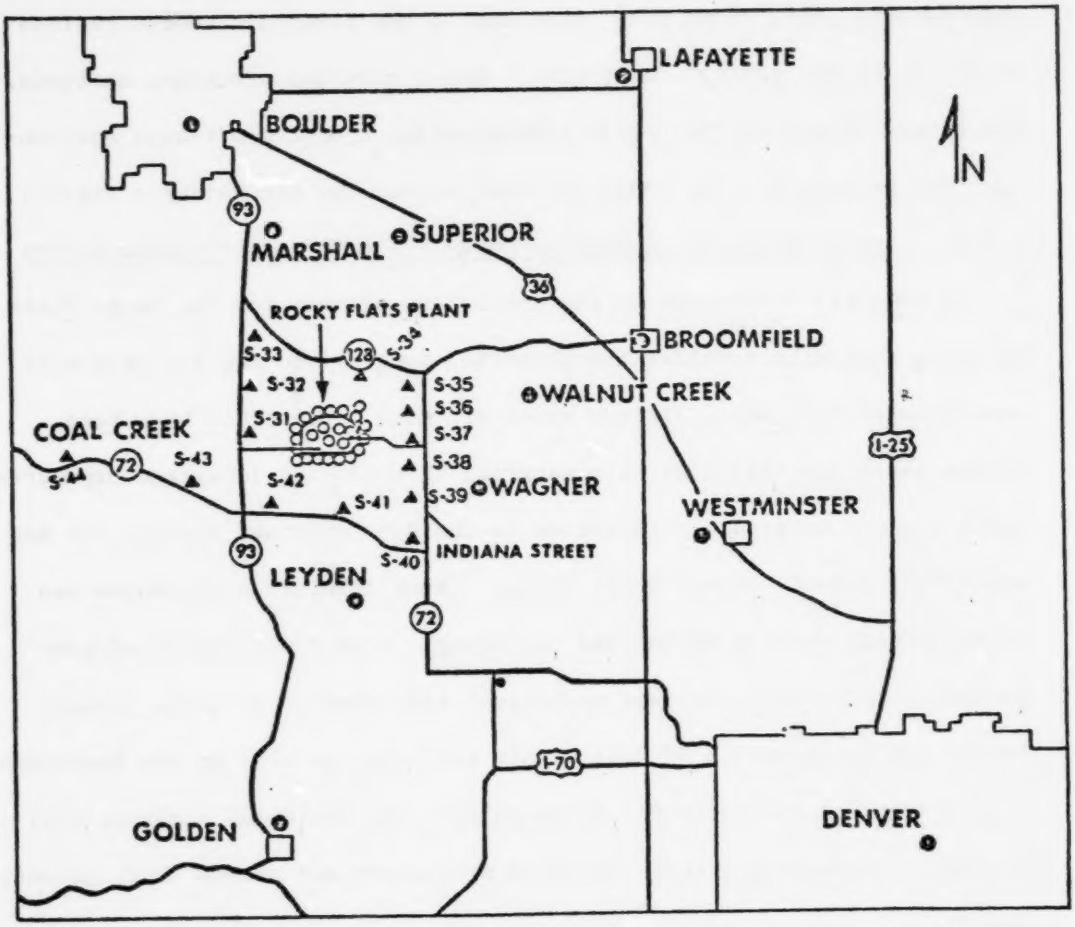
According to Table 7.3, an air concentration of 1.0 fCi/m^3 for 1 µm AMAD aerosols of Pu-239 would produce a 70th year dose rate to the pulmonary compartment of 0.38 mrad/yr; therefore, proportionally, a concentration of 0.056 fCi/m^3 (S-37) will produce a 70th year dose rate of 0.02 mrad/yr. The bone dose rate associated with this level of Pu-239 according to Table 7.4 will be 0.009 mrad/yr in the 70th year.

Data on the air concentration of Am-241 have been reported by HASL (2) for the years 1970 through 1974. These data show the americium levels, measured at the perimeter fence of the Plant, to be approximately 11% of the Pu-239 levels. HASL has also projected that the Am-241 activity level will reach its maximum value arising from the decay of Pu-241 in the year 2033, at which time it will amount to 18% of the Pu-239 activity. For the calculation of the dose rate from Am-241, it is assumed that Am-241 is at the maximum of 18% of the Pu-239. The 70th year dose rate corresponding to a concentration of 1 fCi/m^3 of Am-241 is 0.4 mrad/yr; proportionally, an air concentration of (0.18) (0.056 fCi/m^3) would produce 0.004 mrad/yr to the pulmonary compartment. The associated bone dose would be approximately 0.002 mrad/yr.

Based upon these calculations, the total pulmonary dose rate after 70 years of exposure for an individual living along Indiana Street

FIGURE 7.2

LOCATION OF OFF-SITE AMBIENT AIR SAMPLERS


LAFAYETTE
BOULDER
N
93
MARSHALL
SUPERIOR
36
ROCKY FLATS PLANT
S-33
128
S-34
BROOMFIELD
S-32
S-35
WALNUT CREEK
S-31
S-36
COAL CREEK
S-37
I-25
72
S-43
S-44
S-38
S-42
S-41
S-39
WAGNER
WESTMINSTER
93
INDIANA STREET
S-40
LEYDEN
72
I-70
GOLDEN
DENVER

LEGEND

○ ON-SITE AIR SAMPLERS

▲ AIR SAMPLERS, 3 TO 6 KILOMETERS (2 TO 4 MILES) DISTANCE

● COMMUNITY AIR SAMPLERS

would be 0.024 mrad/yr, while the associated bone dose would be 0.01 mrad/yr. These dose rates are approximately 2.5% and 0.3% respectively of the lung and bone dose rates recommended as guides by EPA (1). Individuals living further away from the Rocky Flats Plant should receive even lower doses than these due to the lower air concentrations reported for the nearby communities. Based upon the preceding analysis, the direct impact of the onsite contamination upon the off-site environment can be judged to be small and well within the EPA guidance limits.

7.2.3 Calculation of Inhalation Doses Due to Off-site Contamination

A complete assessment of the inhalation pathway for the Rocky Flats vicinity must also consider the potential hazard from the low levels of contaminated soil which already exist off-site. Questions have been raised as to the effect of this material in producing localized exposures which are not necessarily reflected in the data obtained through the air monitoring network around Rocky Flats. These inhalation exposures can arise through various mechanisms including: wind resuspension of contaminated soil, vehicular and mechanical disturbances of soil, accumulation and resuspension of dust within the home, as well as the resuspension of contaminated soil attached to clothing. The following analysis will attempt to investigate these exposure mechanisms and assess their potential impact.

Wind Resuspension

Figure 7.3 shows the off-site soil contamination contours reported by HASL in 1970 (3). More recent soil sampling programs in 1975 (9) have not shown these contours to have changed significantly from the

1970

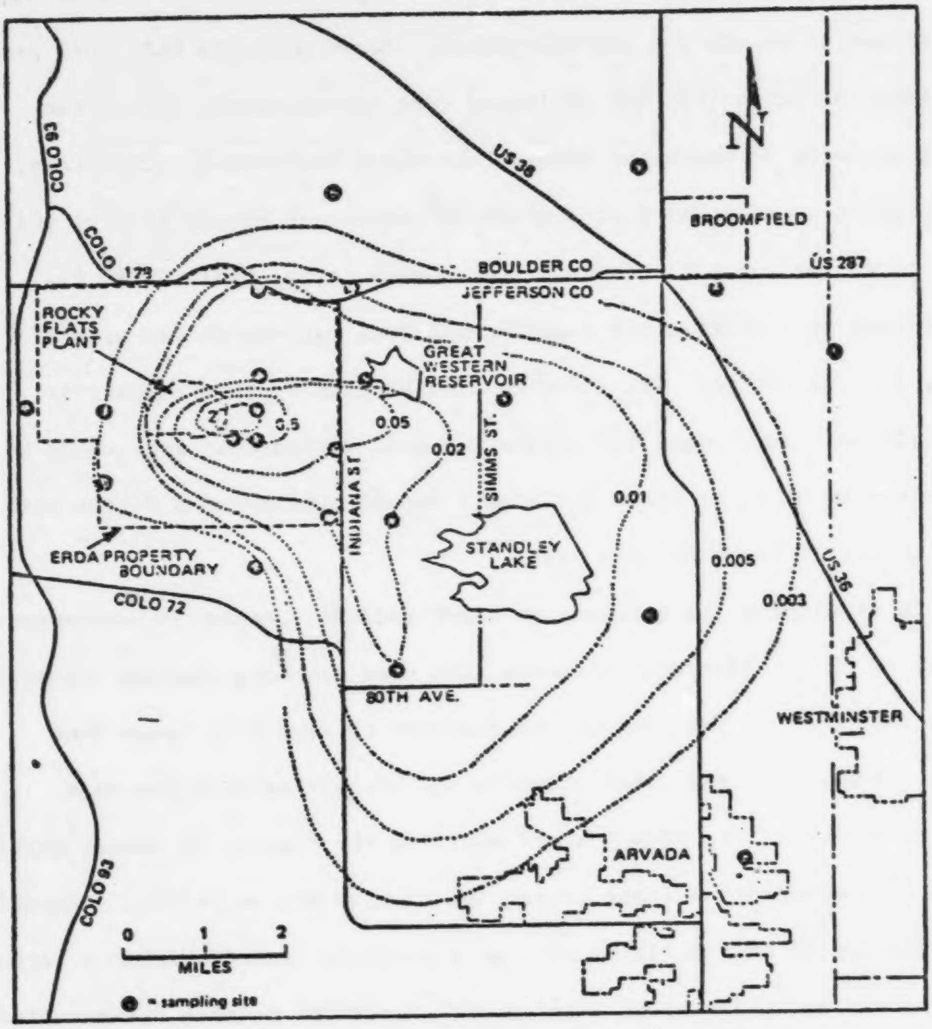

COLO 93
US 36
BROOMFIELD
COLO 128
BOULDER CO
US 287
JEFFERSON CO
ROCKY FLATS PLANT
GREAT WESTERN RESERVOIR
27
0.5
0.05
0.02
INDIANA ST
SIMMS ST.
0.01
STANDLEY LAKE
ERDA PROPERTY BOUNDARY
0.005
0.003
US 36
COLO 72
80TH AVE.
WESTMINSTER
ARVADA
COLO 93
0 1 2
MILES
● = sampling site

FIGURE 7.3 Plutonium-239 Contours Around Rocky Flats (μCi/m²) (adapted from Krey, 1970)

report. The highest off-site contour shown by the HASL data is 0.05 $\mu Ci/m^2$. These contours were developed based upon an inventory sample to a depth of 20 centimeters. What is important in assessing the resuspension of soil, however, is only the material existing near the surface. In the derivation of EPA's guidance (1), the layer subject to erosion was considered to be the top one centimeter. Based upon the HASL soil depth profiles, Anspaugh (10) has estimated that approximately 20% of the total activity is contained within this first centimeter. Therefore, the highest contour value of 0.05 $\mu Ci/m^2$ would correspond to 0.01 $\mu Ci/m^2$ when corrected for a 1 cm. depth. On a mass basis, 0.01 $\mu Ci/m^2$ is equivalent to approximately 2 disintegrations per minute per gram of soil, i.e., 2 DPM/gm. The off-site area bounded by this contour is approximately two square kilometers and soil within that area would be projected to be at or above 2 DPM/gm. Beyond this area, off-site soil will generally be below this value.

In developing its guidance to other Federal agencies on environmental levels of the transuranium elements, EPA used the mass loading approach as an indicator of the general resuspension by wind over large land areas. Because of technical shortcomings identified with the mass loading approach, the agency staff modified the concept to assess small areas of contamination (area correction factor) and to reflect a nonuniform distribution of radioactivity with soil particle size (enrichment factor). This latter modification is particularly important because transuranium activity associated with soil particles within the respirable range is a greater hazard than it would be if associated with the larger nonrespirable particle sizes.

The mass loading approach assumes the loading of the air with particulates to be an index of resuspension and derives the airborne concentration of a specific radionuclide by a comparison with its concentration on the adjacent surface (11). Specifically,

Air Concentration ($\mathrm{fCi}/_{\mathrm{m}}3$) = Soil Concentration ($^{\mu\mathrm{Ci}}/\mathrm{m}^2$) x
Mass Loading ($^{\mu\mathrm{g}}/_{\mathrm{m}}{}^3$) x U.C.* Eq. 1.

Airborne particulate mass loading is one of the criteria for clean air standards, and measurements are widely available for urban and nonurban locations through the National Air Surveillance Network (NASN). The data recorded at nonurban stations are a better indicator of the levels of resuspended material than are urban measurements. In general, annual mean mass concentrations of airborne particulate material at the nonurban stations range from 5-50 micrograms per cubic meter (Figure 7.4); the mean arithmetic average for 1966 of all 30 nonurban NASN stations was 38 $\mu\mathrm{g/m}^3$(11). From Figure 7.4 an estimate can be made of the average mass loading for the general area in which Rocky Flats is located and it would appear that 15 $\mu\mathrm{g/m}^3$ is reasonably representative of this area on an annual basis.

Simple application of the mass loading approach without consideration of the activity distribution as a function of particle size is not appropriate, however, since that would imply a uniform distribution of activity with particle size as well as a uniform

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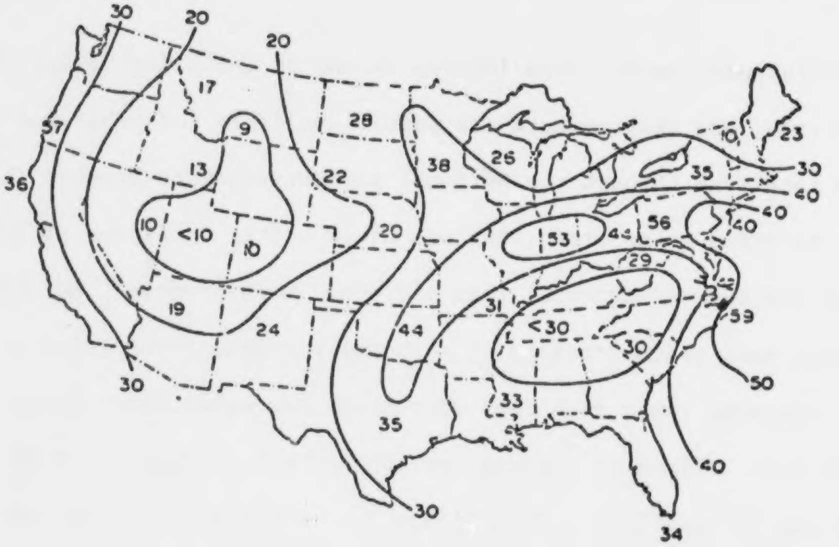
*Where U.C. is the units conversion factor based upon the depth of sampling and the soil density.


30
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57
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<10
10
20
53
44
56
40
29
19
24
31
44
<30
59
30
30
33
50
35
40
30
34

ANNUAL MEAN MASS CONCENTRATIONS (µg/m³) OF AIRBORNE PARTICLES FROM NON-URBAN STATIONS OF THE U.S. NATIONAL AIR SAMPLING NETWORK. 1964 - 1965

FIGURE 7.4

resuspension of all particle sizes. This has not been found to be the case at Rocky Flats (12,13) or at other plutonium contaminated sites (14). In addition, an important consideration in assessing the potential exposure due to contaminated soil is the amount of activity associated with particles within the respirable size range. Johnson (15) has suggested that sampling of only those particles in a soil sample which are within the inhalable size range (generally < 10 μm) would give the best measure of risk to the public health around Rocky Flats. However, the weight fraction of particles in the less than 10 μm range is small in most soils, and sampling, separation, and analysis techniques are correspondingly more difficult and inaccurate. Also, a substantial contribution to other possible pathways (e.g. ingestion) may be via larger particle sizes and measurement of the contribution of only the inhalable fraction would not provide all the information that is required.

In order to adequately assess the potential hazard of the inhalable fraction of soils, while retaining the advantages and convenience of analyzing the entire soil sample, the agency staff modified the mass loading approach by use of an "enrichment factor". While such a concept does not have universal acceptance, and the scope of its applicability has not yet been determined, the agency staff believes that it represents a useful method for the purpose intended and it has therefore been used in this evaluation.

Enrichment Factor

The "Enrichment Factor" is intended to 1) give a mathematical view of the different fractions of the total radioactivity associated with particles of different size ranges, and 2) address the problem of the nonuniform resuspension of particle sizes.

The inhalable fraction of the soil is weighted by considering the relative distribution of activity and soil mass as a function of particle size for representative samples of soil. To accomplish this, the sample of contaminated soil is segregated into "n" size increments and the activity and mass contained within each size increment is determined. The factor g_i is then defined as the ratio of the fraction of the total activity contained within an increment "i" to the fraction of the total mass contained within that increment. A value greater than 1 for g_i implies an enrichment of activity in relation to mass, while a value less than 1 indicates a dilution of the activity with respect to mass. For g_i equal to 1, the fractions of the activity and of the total mass contained within increment "i" are the same.

The nonuniform resuspension of particle sizes is also considered by measuring the mass loading as a function of particle size. The fraction of the airborne mass contained within each size increment "i" is then calculated and designated as f_i. The factors of f_i and g_i are then incorporated into the mass loading formulation as follows:

$$\text{Air Concentration}_i = \text{Air Mass Loading } x f_i x \text{ Soil Concentration } x g_i \qquad \text{Eq. 2}$$

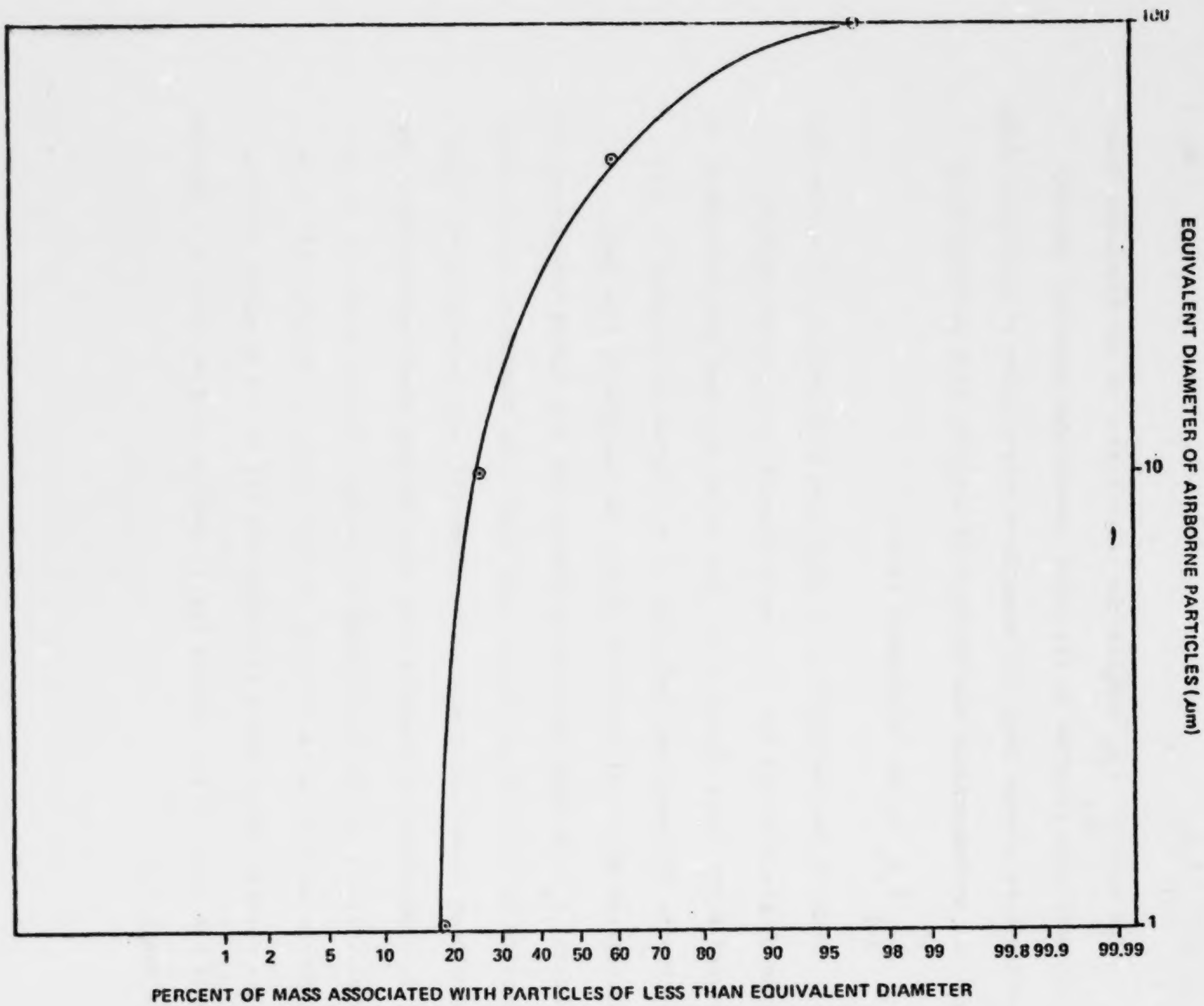
Summation over all the size increments results in the total air concentration:

$$\text{Air Concentration} = \text{Air Mass Loading} \times \text{Soil Concentration} \times \sum_{i=1}^{n} f_i g_i \qquad \text{Eq. 3}$$

The term $\sum_{i=1}^{n} f_i g_i$ weights the contribution of the plutonium from each soil size fraction to the total resuspended material, thereby taking into account both the nonuniform resuspension of particles sizes and the nonhomogeneous distribution of activity with particle size.

$\sum_{i=1}^{n} f_i g_i$ is the "enrichment factor."

Data on the distribution of plutonium with soil particle size has been obtained by the EPA (12) and by Tamura (13) for the vicinity around Rocky Flats (Table 7.5). The ratio, g_i, has been calculated for each size increment and indicates an enrichment of activity to mass associated with soil particles within the respirable size range. To obtain, f_i, the data obtained by Chepil (16) for fields undergoing wind erosion in Colorado and Kansas were used. The results of his findings have been conveniently plotted by Slinn (17) and reproduced as Figure 7.5. Comparison of Chepil's data with another study substantiates the applicability to the Rocky Flats situation. Chepil found 30% of the airborne mass to be below 10 um versus a study by Willeke (18) in an area outside Denver where approximately 33% of the measured airborne mass was below 10 μm. Values for f_i used in this analysis are included in Table 7.5.



PARTICLE SIZE DISTRIBUTION OF RESUSPENDED SOIL

FIGURE 7.5

Correction for Area Size

Use of the mass loading approach implies that the air concentration is at equilibrium with the ground surface, i.e., a steady state situation exists in which the amount of material coming up from the surface is balanced by the rate at which material is depositing back onto the surface. In the strictest sense this limit can only be achieved for source areas approaching infinite dimensions. For sources of finite dimensions, a correction must be applied for area size.

Although techniques are presently under development to calculate the air concentration arising from an area source, no generally accepted method has yet been identified. Usually, these approaches make use of a standard diffusion equation, modified to handle area sources. One such equation is the Sutton-Chamberlain diffusion equation:

$$\frac{\chi}{Q_A} = \frac{1}{V_d}\left[\exp\left(-\frac{4\ V_d\ D_1^{n/2}}{\sqrt{\pi}\ C_2\ n\ u}\right) - \exp\left(-\frac{4\ V_d\ D_2^{n/2}}{\sqrt{\pi}\ C_z\ n\ u}\right)\right] \qquad \text{Eq.4}$$

where χ is the air concentration, Ci/m^3

Q_A is the amount of activity resuspending per unit area, per unit time, Ci/m^2 sec.

V_d is the particle deposition velocity, m/sec.

D_1 and D_2 are the distances from the receptor to the nearest and furthermost edges respectively of the source area, meters.

u is average wind speed, m/sec.

C_z and n are Sutton parameters representing the meteorological conditions.

If the receptor is placed at the downwind edge or within the source area, $D_1 = 0$ and Eq. 4 reduces to:

$$\frac{\chi}{Q_A} = \frac{1}{V_d} \left[1 - \exp\left(- \frac{4\, V_d\, D_2^{\,n/2}}{\sqrt{\pi}\, C_z\, n\, u}\right)\right] \qquad \text{Eq.5.}$$

For source areas approaching infinite depth, $D_2 \rightarrow \infty$ and Eq. 5 becomes:

$$\frac{\chi}{Q_A} = \frac{1}{V_d} \qquad \text{Eq.6.}$$

Comparing Equation 5 with Equation 6 shows that $\left[1- \exp\left(- \frac{4V_d\, D_2^{\,n/2}}{\sqrt{\pi}\, C_z\, n\, u}\right)\right]$ is the correction term to be applied for areas of finite size.

The area under consideration in this analysis has been described earlier. It is bounded by Indiana Street and the 0.05 $\mu Ci/m^2$ isopleth (Figure 7.3) with a width in the downwind direction of approximately 1 kilometer. This is the most highly contaminated off-site area and includes sites of projected residential development. The meteorology for the Rocky Flats area has been described (9) to have neutral stability at least 50% of the time with a mean wind speed of 4.2 m/sec in 1975. Healy (19) has suggested values for the parameters required in Equation 4: for the situation of neutral stability, Healy suggests $C_z = .1$ and $n = .25$, while the ratio $^{V_d}/_{u}$, which depends upon the surface roughness, ranges between 0.003 and 0.008 for grassland, 0.005 will be assumed. Therefore, from Equation 5 the correction factor for the area under consideration is 0.66.

Calculation of the Average Air Concentration Due to Wind Resuspension

The average soil concentration for the area is not known, but it would be somewhere between 0.05 $\mu Ci/m^2$ and the next higher isopleth of 0.5 $\mu Ci/m^2$. For calculational purposes, 0.25 $\mu Ci/m^2$ will be assumed or approximately 10 DPM/g (based upon 20% of the radioactivity within the first centimeter). By using the parameters developed in the previous sections for the Rocky Flats area, one can estimate the average air concentration due to wind resuspension:

Mass Loading x Soil Concentration x Enrichment Factor x Area Correction = Air Concentration

$$15\ \frac{\mu g}{m^3} \times 10\ \frac{DPM}{g} \times 1.63 \times .66 \times \frac{10^{-6} g}{\mu g} \times \frac{Ci}{2.22 \times 10^{12}\ DPM} = \text{Air Concentration}$$

$$0.11\ \frac{fCi}{m^3} = \text{Air Concentration}$$

The calculated value of 0.11 fCi/m^3 agrees with the data obtained for the sampling stations along Indiana Street, and, as demonstrated earlier, this concentration of airborne plutonium would produce exposures well below EPA's guidance limits.

Inherent in the above calculation were some conservative assumptions. First of all, the wind was assumed to be blowing 100% of the time across the contaminated area in the direction of the receptor. In reality, the reported (9) wind rose for Rocky Flats indicates that the wind blows from the westerly direction only about 50% of the time; the remaining time it will be blowing from the direction of less contaminated land and, therefore, less radioactivity would be available for resuspension. Secondly, in deriving the area correction factor the effect of breathing height was ignored with the ground level concentration being calculated. This is a conservative assumption since the airborne concentration will decrease as a function of the height above the ground. Although such refinements could have been incorporated in the calculation, it was not felt to be necessary because even these conservative assumptions resulted in air concentrations well below the Agency's proposed guidance.

Resuspension of Soil by Mechanical Disturbances

The use of land contaminated with transuranium elements in the vicinity of Rocky Flats for agricultural or building purposes can result in localized resuspension and presents a potential inhalation hazard to individuals in the immediate vicinity of the operation. In the vicinity of Rocky Flats, there is some farming of wheat and the raising of corn for livestock feed. Future development of the land for residential purposes is also being advocated. Although only a limited amount of experimental data is currently available as a basis for an assessment of the inhalation hazard from such activities, some conclusions and recommendations can be made.

In assessing the agricultural situation, data obtained by Milham (20) have been used. In that study, a field contaminated with plutonium near the Savannah River Facility was subjected to various plowing and seeding activities associated with planting wheat. The increase in the airborne activity above that from normal wind resuspension was monitored at the location of the tractor operator and at the downwind edge of the field during the various activities. An average increase of a factor of 30 was observed in the level of resuspended plutonium at the location of the tractor operator and an increase of a factor of 5 at the edge of the field. Based upon these observations, the average air concentration for the year can be calculated for these two locations, assuming that the field is cultivated 30 days of the year for 8 hours per day. Again the area under consideration will be that area of highest off-site contamination described earlier with an average soil contamination level of 10 DPM/g. In the previous discussion of wind resuspension, this level of soil activity produced an air concentration of 0.11 fCi/m^3. From Milham's data, this activity level would increase to 3.0 fCi/m^3 at the location of the tractor operator and to 0.55 fCi/m^3 at the edge of the field during the agricultural operations. The annual average concentration at each location is therefore:

1. Tractor Location, Average Annual Air Concentration

$$3.0 \text{ fCi/m}^3 \times \frac{8}{24} \times \frac{30}{360} + 0.11 \text{ fCi/m}^3 \times \frac{16}{24} \times \frac{30}{360} + 0.11 \text{ fCi/m}^3 \times \frac{330}{360} = 0.2 \text{ fCi/m}^3$$

2. Edge of Field, Average Annual Air Concentration

$$0.55 \times \frac{8}{24} \times \frac{30}{360} + 0.11 \times \frac{16}{24} \times \frac{30}{360} + 0.11 \times \frac{330}{360} = 0.12 \text{ fCi/m}^3$$

When these annual Pu-239 concentrations are compared to the value of 2.6 fCi/m^3 which was calculated by the PAID code to correspond with

EPA's dose limits, one can conclude that agricultural operations in the area of Rocky Flats would produce activity levels well within EPA's guidelines. In addition, after the first plowing cycle, the surface concentration should be diluted by mixing with soil from below the surface and subsequent plowings would produce air concentration lower than that of the first year.

Regarding building activities, one can make projections based upon the agricultural situation examined above. There does not appear to be any reason why building activities, such as excavation and grading, should produce higher instantaneous air concentrations than those observed during agricultural plowing and, therefore, they should not present a more restrictive situation. In addition, although the building activity might take place for longer than the 30 days assumed in the plowing situation, it must be kept in mind that the EPA guidelines are based upon a chronic exposure for 70 years. Certainly, the bulldozer operator would not be engaged in a building operation in an area of transuranium contamination for that number of years.

Resuspension of Dust Within the Home

The total amount of soil continuously in the home is not known but an assumption of 10 g/m^2 has been made (21). This amounts to about 3 lbs of soil in a modest 1500 ft^2 house. Because the floors are harder and smoother than outside surfaces, the resuspension from them will be higher. Resuspension factors of 10^{-6} m^{-1} have been used in the past to predict exposures in the work place and studies of PuO_2 deposited on indoor surfaces have been consistent with a resuspension factor of 10^{-6} m^{-1} (22).

The following exposure situation is postulated: the individual is exposed to contaminated dust in the home for 24 hrs/day, 7 days/wk, for 70 years. The dust in the home has the same activity/gram as outside soil and has an areal distribution within the home of 10 g/m^2. The air concentration resulting from resuspended dust at 10 DPM/g would be:

$$10\ \frac{\text{DPM}}{\text{g}} \times \frac{\text{Ci}}{2.22\text{x}10^{12}\ \text{DPM}} \times \frac{10\text{g}}{\text{m}^2} \times \frac{10^{-6}}{\text{m}} = \text{airborne dust concentration}$$

$$0.045\ \text{fCi/m}^3 = \text{airborne dust concentration}$$

Again the level of airborne activity would result in dose rates well within EPA's guidance limits.

Resuspension of Dust from Contaminated Clothing

Healy (19) has assumed that in a desert environment there will be 1 mg/cm^2 ($10g/m^2$) of dust on clothing. While it would certainly be less for nondesert environments, this value will also be assumed for Rocky Flats. Because of the proximity of the contamination to the nose and the mouth, a resuspension factor higher than the normal outdoor resuspension factor will be assumed. For this calculation, a value of 10^{-6} m^{-1} will be assumed to be sufficiently conservative (10^{-6} m^{-1} is 3-4 orders of magnitude higher than values of wind resuspension factors observed at Rocky Flats). Therefore, the resultant air concentration is:

$$\frac{10\text{g}}{\text{m}^2} \times 10\ \frac{\text{DPM}}{\text{g}} \times \frac{\text{Ci}}{2.22\text{x}10^{12}\ \text{DPM}} \times \frac{10^{-6}}{\text{m}^{-1}} = 0.045\ \text{fCi/m}^3$$

In addition to this air concentration being much lower than EPA's guidelines, the period of exposure would not be continuous since the clothing would be removed at least during sleeping. Therefore this pathway would present no apparent hazard.

7.2.4 Conclusion

None of the inhalation pathways considered in the environs surrounding the Rocky Flats Facility has resulted in doses close to the guidance limits recommended by EPA for the transuranium elements. Even if the conservative assumption is made that these exposures are occurring simultaneously, the combination of pathways would amount to only a few percent of the guidance limits. Even though every conceivable inhalation pathway was not evaluated, it does not seem likely that one exists which would have a combination of resultant air concentration and period of exposure to produce significant doses compared to the guidance levels.

7.3 Ingestion Pathway

7.3.1 Plutonium and Americium in Drinking Water

Wastewater discharged from the Rocky Flats Plant as well as surface runoff from the Plant site is collected in a number of holding ponds where it is monitored for its radioactivity content before being discharged into either Walnut or Woman Creek. Walnut Creek empties into the Great Western Reservoir which provides part of the drinking water supply for the City of Broomfield, while Woman Creek eventually empties into Standley Lake which is a drinking water supply for the City of Westminster.

The Rocky Flats water monitoring program consists of 1) effluent monitoring of the water being discharged from the holding ponds into Walnut and Woman Creeks, 2) the monitoring of groundwater and 3) the monitoring of the regional water supplies. In monitoring public water supplies, samples are collected and analyzed from the drinking water reservoirs (Great Western and Standley Lake) as well as the finished water in several nearby communities. As with the air monitoring, the results of this sampling program are reported regularly to the responsible Federal, State, and local government agencies and published on a yearly basis. According to the 1975 published data (9) the average concentrations of plutonium and americium in finished water for the region were $< .027\text{x}10^{-9}$ μCi/ml and $< .032\text{x}10^{-9}$ μCi/ml, respectively. The concentration levels of plutonium and americium in the drinking water of the various communities surrounding Rocky Flats are given in Table 7.6. Included in this Table are results obtained by Poet and Martell (23) in 1970. Limited comparison of the two sets of data shows little change in the activity levels in the drinking water during this five year period. As with the airborne concentrations, these environmental levels need to be put into the perspective of EPA's guidance limits.

7.3.2 Bone Dose Resulting Due to Ingestion of Water

Assuming that the concentrations of Pu-239 and Am-241 in drinking water are those reported for the city of Broomfield (the highest concentrations reported for the more immediate surrounding communities) and that the consumption rate of water is 1.2 liters/day (ICRP Committee

II) the annual water ingestion rates are:

Pu-239, Annual Ingestion Rate

$$0.04\times10^{-9}\ \frac{\mu Ci}{ml} \times 1200\ \frac{ml}{day} \times \frac{365d}{yr} = 18\ pCi/yr$$

Am-241, Annual Ingestion Rate

$$0.029\times10^{-9}\ \frac{\mu Ci}{ml} \times 1200\ \frac{ml}{day} \times \frac{365d}{yr} = 13\ pCi/yr$$

Conversion of the above ingestion rates into dose rates can be achieved through the use of Tables 7.7 and 7.8. The development of these tables has been described in Annex III of EPA's guidance (1). Table 7.8 has been normalized to an ingestion rate of 1000 pCi/yr of various transuranium oxides and relates the years of ingestion to the resulting dose rate. Plutonium and americium found in treated tap water would probably be in a chemical form which is more soluble than the oxide and which would have a higher GI tract transfer fraction (24). For nonoxide forms, as shown in Table 7.7, the values listed in Table 7.8 should be increased by a factor of 10 for plutonium, while the americium values remain the same. Based upon these conversion factors, the bone dose rate after 70 years of ingestion of drinking water would be 8.8×10^{-3} mrad/yr for Pu-239 and 6.2×10^{-3} mrad/yr from Am-241. These values are considerably below EPA's recommendation of 3 mrad/yr to bone from the transuranium elements.

7.3.3. Bone Dose Due to Ingestion of Foodstuffs

At present limited agricultural production is carried out in the environs of Rocky Flats. Most of the food consumed locally is produced at considerable distances from the Rocky Flats Plant. Other than a few family garden plots, the only crops grown locally are wheat and alfalfa. A few cattle also are raised in the Plant's vicinity. Since future residential development is projected for the Rocky Flats area, it would be reasonable to project a concurrent increase in family gardening. Therefore, an assessment has been carried out of the possible dose rates associated with the consumption of foodstuffs which might be produced locally. Because food sampling data are not presently available for the Rocky Flats area, estimation of the potential doses are based upon data developed in other areas contaminated with transuranium elements and from laboratory experiments of transuranium uptake by foodstuffs. Conditions at Rocky Flats are not different enough to invalidate the use of data developed in these other environments.

For purposes of this assessment, the ingestion rate of the transuranium elements by people is considered to be the product of the rates at which different contaminated materials are ingested and the concentration of the transuranium elements in each material.

To put these calculations into perspective, the formulation of Martin and Bloom (25) was adopted which relates the ingestion rate (H) for a particular nuclide to the average concentration of that nuclide in soil (C_s) through the following formulation:

$$H = C_s I_i D_i \qquad \text{Eq. 7.}$$

where I_i is the ingestion rate of a particular item and D_i is the discrimination ratio between that substance and soil. This formulation makes for easy translation of environmental levels into dose rates and, thereby, allows direct comparison with EPA's guidance limits.

The soil concentration used in this assessment is the same as that developed for the inhalation pathway calculations, i.e., 0.25 $\mu Ci/m^2$ for Pu-239 and 0.045 $\mu Ci/m^2$ for Am-241 (18% of Pu-239 levels at the time of maximum ingrowth). If this activity is evenly distributed throughout the top 20 cm as a result of plowing, the average concentration, C_s, in units of pCi/g would be:

$$0.25 \frac{\mu Ci}{m^2} \times 10^6 \frac{pCi}{\mu Ci} \times \frac{cm^3}{1g} \times \frac{1}{20\ cm} \times \frac{m^2}{10^4\ cm^2} = 1.25\ pCi/g\ \text{Pu-239}$$

and 0.22 pCi/g (Am-241).

The materials considered by this analysis to be produced on this land and consumed by individuals living in the area are leafy vegetables, other food plants, cow milk, and beef. Also the casual and deliberate ingestion of contaminated soil will be considered.

Leafy Vegetables and Other Food Plants

Plants grown in soil containing the transuranium elements can become contaminated through uptake by the roots and systemic incorporation; in addition, the outer surfaces of the plant can have contaminated soil deposited upon them as a result of resuspension. Numerous studies have been conducted and several reviews (26, 27, 28) have been published covering the range of discrimination factors that have been observed in laboratory and field studies. generally the discrimination ratio for incorporation of Pu-239 into the plant is between 10^{-4} to 10^{-6} on a fresh weight basis and 10^{-1} to 10^{-2} for deposition on the plant surface. The internal incorporation of americium-241 may be as much as 50 times higher than that of plutonium, due to its greater solubility. Generally, uptake factors for garden vegetables are at the upper end of the range; therefore, for calculational purposes a discrimination ratio of 10^{-4} will be assumed for internal deposition and 10^{-1} for external deposition when computing the intake of Pu-239, and corresponding ratios of 5×10^{-3} and 10^{-1} for Am-241. Since the calculations are for food in a table-ready condition, decontamination of the food during processing must also be recognized. In doing so, the assumption of Bloom and Martin (25) will be used; namely, 90% of the contamination is washed off leafy vegetables and 99% of the contamination is removed from other food plants during washing, peeling, etc. Likewise, the consumption rates of foodstuffs obtained by Martin and Bloom from the USDA have been used after conversion to a fresh weight basis (on the basis that vegetation is 70% water). Table 7.9 contains the resultant ingestion rates and discrimination ratios used in this assessment.

Equation 7 was used to convert the ingestion rates and discrimination factors of Table 7.9 into annual intakes of plutonium and americium. In carrying out the food pathway calculations, the assumption was made that 25% of the entire intake for an individual arises from foodstuffs produced locally on land contaminated with transuranium elements.

The resultant ingestion doses are given in Table 7.10. In converting the annual radionuclide intake to dose rates, Table 7.7 and 7.8 were used with the following assumptions:

1. the duration of ingestion is 70 years
2. externally deposited material is in the oxide form

and 3. material biologically incorporated in plants and animals is assumed to have a greater fraction transferred from the G.I. tract to the blood. For plutonium, according to Table 7.7, this results in an increase of a factor of 50 in the resulting bone dose and a factor of 5 for americium.

Ingestion of Cow Milk

Martin and Bloom have developed a discrimination factor for dairy cows of $3.2\text{x}10^{-8}$ based upon assumptions of soil and vegetation consumption by cattle. Using this value and again assuming that 25% of one's diet is locally produced, one can calculate the ingestion rates of Pu-239 and Am-241 as a result of milk consumption:

$$H\ (\text{Pu-239}) = C_s\ ID$$

$$= 1.25\ \frac{\text{pCi}}{\text{g}} \times \frac{436\text{g}}{\text{day}} \times .25 \times 365\ \frac{\text{days}}{\text{yr}} \times 3.2\text{x}10^{-8}$$

$$H\ (\text{Pu-239}) = 1.6\text{x}10^{-3}\ \text{pCi/yr}$$

$$H\ (\text{Am-241}) = .18\ H\ (\text{Pu-239})$$

$$H\ (\text{Am-241}) = .28\text{x}10^{-3}\ \text{pCi/yr}$$

Since these transuranium elements would be biologically incorporated, the dose rates of Table 7.8 would be increased by a factor of 50 for Pu-239 and a factor of 5 for Am-241. The resultant bone doses attributable to the consumption of milk are given in Table 7.9.

Ingestion of Beef

Similarly, Martin and Bloom developed discrimination factors for beef muscle and beef liver and these have been utilized in our calculations of ingestion rates:

Beef Muscle

$$H\ (\text{Pu-239}) = C_s\ ID$$

$$H\ (\text{Pu-239}) = 1.25\ \frac{\text{pCi}}{\text{g}} \times \frac{273\ \text{g}}{\text{day}} \times .25 \times \frac{365\text{d}}{\text{yr}} \times 3.3\text{x}10^{-5}$$

$$H\ (\text{Pu-239}) = 1.02\ \text{pCi/yr}$$

$$H\ (\text{Am-241}) = .18\ H\ (\text{Pu-239})$$

$$H\ (\text{Am-241}) = 1.85\text{x}10^{-1}\ \text{pCi/yr}$$

Beef Liver

$$H\ (\text{Pu-239}) = 1.25\ \frac{\text{pCi}}{\text{g}} \times \frac{13\text{g}}{\text{day}} \times .25 \times 365\ \frac{\text{day}}{\text{yr}} \times 2.\text{x}10^{-3}$$

$$H\ (\text{Pu-239}) = 2.96\ \text{pCi/yr}$$

$$H\ (\text{Am-241}) = .18\ H\ (\text{Pu-239})$$

$$H\ (\text{Am-241}) = 5.33\text{x}10^{-1}\ \text{pCi/yr}$$

Assuming that transuranium material is biologically incorporated, the resultant bone dose rates after 70 years of ingestion have been calculated and are included in Table 7.10.

7.3.4 Bone Dose Due to Soil Ingestion

Casual Ingestion

Bloom and Martin (25) have assumed a casual ingestion rate for a desert environment to be approximately 3-4 g/year. Likewise, Rogers (21) has estimated the accidental ingestion rate of soil as a result of hand to mouth transfer to be 3-4 g/yr. Based upon these estimates, one can calculate the plutonium and americium ingestion and resulting dose rates. The ingestion period is assumed to be 70 years and the surface soil concentration of Pu-239 is that developed previously for unplowed, undiluted soil in the vicinity of Indiana Street; i.e., 10 DPM/g (4.5 pCi/g). The americium concentration, also as before, is assumed to be at its maximum contribution of 18% or 0.8 pCi/g. The resulting bone dose have been calculated assuming the transuranic material is in the oxide form and these have been included in Table 7.10.

Deliberate Ingestion

Healy (29) has addressed the problem of deliberate soil ingestion by children below the age of five. After reviewing the limited available data on the topic, he concluded that a deliberate soil ingestion rate of 20 g/day would be a reasonably severe case. Applying this estimate to the Rocky Flats situation would produce the following ingestion rates for deliberate soil ingestion:

$$H\ (\text{Pu-239}) = C_s\ ID^*$$

$$= 4.5\ \text{pCi/g} \times \frac{20\text{g}}{\text{day}} \times 365\ \frac{\text{days}}{\text{yr}}$$

$$H\ (\text{Pu-239}) = 3.24\text{x}10^4\ \text{pCi/yr}$$

---

* D is equal to 1.0

$$H\ (\text{Am-241}) = .18\ (\text{Pu-239})$$

$$H\ (\text{Am-241}) = 5.84\text{x}10^{3}\ \text{pCi/yr}$$

Since this condition of excessive soil ingestion would occur over a relatively few years, the resultant dose rates were calculated assuming the period of ingestion to be 5 years and are included in Table 7.10.

7.3.5 Conclusions

From the results presented in Table 7.10, one can conclude that, even for the unlikely case where the calculated doses for all pathways are additive, the doses received by ingestion would be well below the EPA guideline of 3 mrad/yr to bone. In reality, an individual in the vicinity of Rocky Flats would receive much lower doses than those calculated. It is deemed very unlikely that one could identify other possible ingestion pathways of such magnitude that they would result in bone doses exceeding 3 mrads in any year.

Table 7.1

SURFACE AIR PU-239 CONCENTRATION AT ROCKY FLATS
ATTOCURIES/CUBIC METER

		JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
SITE #1	1970	--	--	--	--	--	1990.00	1250.00	790.00	850.00	693.00	2260.00	962.00
	1971	1960.00	--	7140.00	9730.00	4920.00	3800.00	2980.00	3530.00	4040.00	5770.00	5770.00	3160.00
	1972	5430.00	1670.00	4610.00	1460.00	2080.00	6610.00	4720.00	1380.00	--	1620.00	498.00	1860.00
	1973	1160.00	3640.00	2520.00	612.00	1780.00	3040.00	2920.00	3320.00	1050.00	2010.00	1810.00	1690.00
	1974	402.00	802.00	891.00	1810.00	3060.00	5470.00	2670.00	3330.00	1120.00	407.00	580.00	643.00
	1975	1260.00	1360.00	1780.00	2180.00	2190.00	1160.00	567.00	426.00	179.00	--	1220.00	655.00
	1976	680.00	1240.00	864.00	--	--	--	--	--	--	--	--	--
SITE #2	1972	--	--	--	--	--	--	98.90	55.50	119.00	609.00	48.50	45.20
	1973	37.80	57.70	55.80	716.00^c	51.80	57.70	92.10	65.00	152.00	31.50	25.20	76.30
	1974	16.80	23.20	462.00^c	135.00	176.00	140.00	78.70	58.10	34.20	24.00	29.20	43.70
	1975	141.00	34.70	56.80	39.70	--	--	27.40	14.00	9.98	--	10.60	16.40
	1976	12.20	23.10	14.40	--	--	--	--	--	--	--	--	--
SITE #3	1972	--	--	--	--	--	--	--	--	--	21.90	18.50	25.60
	1973	18.40	41.70^a	24.20	24.00	40.40	42.00	25.80	25.70	38.20	21.50	11.00	16.90
	1974	21.70	39.10	163.00^c	283.00^c	--	--	--	--	--	--	--	--
SITE #4	1974	--	--	--	--	1460.00	758.00	1430.00	222.00	199.00	395.00	1240.00	710.00
	1975	288.00	399.00	1850.00	254.00	139.00	684.00	118.00	146.00	72.20	189.00	188.00	128.00
	1976	184.00	303.00	72.60	236.00	109.00	319.00	98.20	63.10	--	--	--	--

-- NO DATA

Errors are less than 20% except:
- a -error between 20% and 100%
- b -error greater than 100%
- c -suspect, omitted from average

* Table from reference 2.

Table 7.2

Plutonium in Three-to Six-Kilometer-(2-to 4-Miles-)Distant Ambient Air

Station	Number of Samples Taken	Less Than Detectable	Volume (cubic meters)	Concentration($x10^{-15}$ µCi/ml)	
				$C_{maximum}$	$C_{average}$[a]
S-31	12	1	461,547.0	0.144	<0.032 ± 96%
S-32	12	1	543,346.0	0.134	<0.035 ± 96%
S-33	12	1	531,886.0	0.097	<0.034 ± 95%
S-34	3	1	118,243.0	0.176	<0.037 ± 550%
S-35	3	0	119,322.0	0.116	0.027 ± 538%
S-36	2	0	57,286.0	0.012	0.012 ± 1734%
S-37	12	0	525,181.0	0.198	0.056 ± 93%
S-38	10	0	460,089.0	0.097	0.027 ± 108%
S-39	12	1	502,129.0	0.102	<0.026 ± 97%
S-40	12	0	486,876.0	0.198	0.054 ± 92%
S-41	12	1	472,698.0	0.136	<0.033 ± 99%
S-42	12	1	416,244.0	0.137	<0.037 ± 96%
S-43	11	1	360,818.0	0.185	<0.056 ± 105%
S-44	12	1	429,709.0	0.094	<0.029 ± 103%
Summary	137	9	5,485,374.0	0.198	-
Volume-Weighted Average					<0.037 ± 29%

---

a. Volume-weighted average.

* Table from reference 9.

Table 7.3

Annual Dose Rate to Various Lung Compartments from Chronic Exposure to Plutonium and Americium Aerosols

(Concentration = 1 fCi/m^3 and Particle AMAD = 0.05, 1.0, and 5.0 micrometers)

Plutonium-239

Duration of Exposure years	Pulmonary mrad/yr x 10^{-1}			Tracheo bronchial mrad/yr. x 10^{-2}			Nasopharyngeal mrad/yr x 10^{-6}		
	0.05µ	1.0µ	5.0µ	0.05µ	1.0µ	5.0µ	0.05µ	1.0µ	5.0µ
1	3.9	1.5	.7	2.7	1.1	6.1	.04	11.	30.
5	9.1	3.5	1.7	3.7	1.5	7.9	.04	11.	30.
10	9.8	3.8	1.8	3.8	1.6	8.1	.04	11.	30.
70	9.9	3.8	1.8	3.8	1.6	8.1	.04	11.	30.

Americium-241

Duration of Exposure years	Pulmonary mrad/yr x 10^{-1}		
	0.5µ	1.0µ	5.0µ
70	10.	4.2	1.9

Table 7.4

Annual Dose Rates to Various Organs from Chronic Exposure to Plutonium-239 and Americium-241 Aerosols AMAD=1μ; Concentration 1 fCi/m^3

Duraction of Exposure (years)	Pu-239 (mrad/year) Liver	Pu-239 (mrad/year) Bone	Pu-239 (mrad/year) T-B Lymph Nodes	Am-241 (millirad/year) Liver	Am-241 (millirad/year) Bone	Am-241 (millirad/year) T-B Lymph Nodes
1	.001	.0005	.40	.0015	.0005	.39
5	.018	.0065	4.0	.019	.007	4.2
10	.052	.019	7.0	.055	.021	7.4
15	.089	.034	8.7	.095	.036	9.1
20	.13	.049	9.8	.13	.052	10
30	.19	.078	12	.20	.082	12
40	.24	.11	14	.26	.11	14
50	.29	.13	15	.30	.14	16
70	.36	.17	19	.37	.18	20

Table 7.5

Sample	Size Increment (μm)	Wgt. Fract.	Act. Fract.	g_i	f_i	$\sum_i f_i g_i$
RF 1A	2000-105	.62	.07	.12	-	
	105-10	.18	.40	2.21	.7	
	<10	.20	.53	2.65	.3	2.34
RF 1B	2000-105	.63	.39	.63	-	
	105-10	.17	.06	.34	.7	
	<10	.20	.55	2.74	.3	1.06
RF 1C	2000-105	.64	.43	.68	-	
	105-10	.16	.07	.46	.7	
	<10	.20	.49	2.47	.3	1.06
RF 2A	2000-105	.46	.13	.28	-	
	105-10	.34	.37	1.10	.7	
	<10	.20	.50	2.48	.3	1.51
					av.	1.49
Tamura	2000-105*	.47	.11	.23	-	
	105-10	.42	.61	1.45	.7	
	<10	.11	.28	2.54	.3	1.78

*Data only for untreated samples and normalized to particle sizes less than 2000 μm.

Overall Average 1.63

Table 7.6*

Plutonium and Americium in Public Water Supplies

		Plutonium Concentration (x 10^{-9} μCi/ml)		
Reservoirs	Number of Samples Taken	$C_{minimum}$	$C_{maximum}$	$C_{average}$[b]
Great Western	36	<0.013	0.952	<0.099 ± 58%
Great Western[a]		.046	.214	
Standley Lake	36	<0.013	0.142	<0.036 ± 23%
Summary	72	<0.013	0.952	-
Finished Water				
Arvada	11	<0.005	0.019	<0.006 ± 50%
Boulder	12	<0.005	0.014	<0.007 ± 17%
Broomfield	39	<0.013	0.133	<0.041 ± 26%
Broomfield[a]			.038	
Denver	11	<0.005	0.016	<0.008 ± 29%
Golden	11	<0.005	0.048	<0.009 ± 107%
Lafayette	12	<0.005	0.030	<0.007 ± 67%
Louisville	11	<0.005	0.012	<0.006 ± 21%
Thornton	12	<0.005	0.018	<0.009 ± 32%
Westminster	36	<0.013	0.210	<0.041 ± 31%
Summary	155	<0.005	0.210	-
Average	-	-	-	<0.027 ± 49%

		Americium Concentration (x 10^{-9} μCi/ml)		
Reservoirs	Number of Samples Taken	$C_{minimum}$	$C_{maximum}$	$C_{average}$[b]
Great Western	38	0.014	<0.090	<0.033 ± 20%
Standley Lake	37	<0.013	<0.090	<0.027 ± 19%
Summary	75	<0.013	<0.090	-
Finished Water				
Arvada	11	<0.001	0.239	<0.026 ± 180%
Boulder	11	<0.001	0.015	<0.006 ± 180%
Broomfield	37	<0.023	0.150	<0.029 ± 31%
Denver	11	<0.001	0.420	<0.043 ± 196%
Golden	11	<0.001	0.044	<0.009 ± 80%
Lafayette	12	<0.001	0.030	<0.007 ± 67%
Louisville	12	<0.001	0.400	<0.039 ± 185%
Thornton	12	<0.001	0.007	<0.005 ± 3%
Westminster	39	<0.013	0.079	<0.029 ± 18%
Summary	156	<0.001	0.420	-
Average	-	-	-	<0.032 ± 25%

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* Table from reference 9 .

a. Data of Poet and Martell (1970)

b. Sample-weighted average

Table 7.7

Fraction of Ingestion Material Transferred to Blood from the Gastrointestinal Tract

Radionuclide	Transfer Fraction non-oxide	Transfer Fraction oxide	Biologically Incorporated
Plutonium-238	10^{-3}	10^{-3}	$5x10^{-3}$
Plutonium-239	10^{-3}	10^{-4}	$5x10^{-3}$
Plutonium-240	10^{-3}	10^{-4}	$5x10^{-3}$
Plutonium-241	10^{-3}	10^{-3}	$5x10^{-3}$
Americium-241	10^{-3}	10^{-3}	$5x10^{-3}$
Curium-244	10^{-3}	10^{-3}	$5x10^{-3}$

Table 7.8

Annual Dose Rate Due to Chronic Ingestion of Plutonium-239 Oxide, Americium-241, Plutonium-241 and Curium-224 Annual Intake 1000 pCi/Year

Duration of Ingestion Years	Plutonium-239 Oxide (µrad/year) Bone	Liver	Whole Body	Americium-241 (µrad/year) Bone	Liver	Whole Body
1	0.9	2.4	4.6x10^{-3}	9.2	2.5x10^{1}	4.9x10^{-2}
5	4.3	1.2x10^{1}	2.7x10^{-2}	4.5x10^{1}	1.2x10^{2}	2.4x10^{-1}
10	8.4	2.2x10^{1}	4.5x10^{-2}	8.8x10^{1}	2.3x10^{2}	4.7x10^{-1}
15	1.2x10^{1}	3.2x10^{1}	6.6x10^{-2}	1.3x10^{2}	3.4x10^{2}	6.9x10^{-1}
20	1.6x10^{1}	4.1x10^{1}	8.6x10^{-2}	1.7x10^{2}	4.3x10^{2}	9.0x10^{1}
30	2.4x10^{1}	5.6x10^{1}	1.3x10^{-1}	2.4x10^{2}	5.9x10^{2}	1.3
40	3.0x10^{1}	6.9x10^{1}	1.6x10^{-1}	3.1x10^{2}	7.2x10^{2}	1.7
50	3.7x10^{1}	8.1x10^{1}	1.9x10^{-1}	3.8x10^{2}	8.3x10^{2}	2.0
70	4.8x10^{1}	9.8x10^{1}	2.6x10^{-1}	4.9x10^{2}	9.9x10^{2}	2.6

Table 7.9

Food Ingestion Rates and Radionuclide Discrimination Ratios

Substance	Ingestion Rate(g/day)	Discrimination Ratio	
Leafy Vegetables	270[b]	Pu(ext.)	$[10^{-1} \times 10\%]$
		Pu(int.)	10^{-4}
		Am(ext.)	$[10^{-1} \times 10\%]$
		Am(int.)	5×10^{-3}
Other Vegetables	740[b]	Pu(ext.)	$[10^{-1} \times 1\%]$
		Pu(int.)	10^{-4}
		Am(ext.)	$[10^{-1} \times 1\%]$
		Am(int.)	5×10^{-3}
Cow Milk	436	Pu[a]	3.17×10^{-8}
		Am[c]	3.17×10^{-8}
Beef Muscle	273	Pu[a]	3.29×10^{-5}
		Am[c]	3.29×10^{-5}
Beef Liver	13	Pu[a]	2.0×10^{-3}
		Am[c]	2.0×10^{-3}
Soil (casual)	.01	Pu	1.0
		Am	1.0
Soil (deliberate)	20	Pu	1.0
		Am	1.0

---

a. from ref. 25.
b. assumes vegetation is 70% water
c. assumes retention and transport within cow is the same for Pu and Am

Table 7.10

Ingestion and Resultant Bone Dose Rates

Substance	Radionuclide	Ingestion Rates (pCi/yr)	70th Year Bone Dose Rate (mrad/yr)
Drinking Water	Pu	18	8.8×10^{-3}
	Am	13	6.2×10^{-3}
Leafy Vegetables	Pu (ext.)	297	.014
	Pu (int.)	3	.071
	Am (ext.)	53	.026
	Am (int.)	27	.067
Other Vegetables	Pu (ext.)	82	.004
	Pu (int.)	9	.020
	Am (ext.)	15	.007
	Am (int.)	74	.018
Cow Milk	Pu	1.6×10^{-3}	$.40\times10^{-5}$
	Am	$.28\times10^{-3}$	$.67\times10^{-6}$
Beef Muscle	Pu	1.02	2.5×10^{-3}
	Am	1.85×10^{-1}	2.8×10^{-4}
Beef Liver	Pu	2.96	7.1×10^{-3}
	Am	5.33×10^{-1}	1.28×10^{-3}
Soil (casual)	Pu	18.0	8.6×10^{-4}
	Am	3.2	1.6×10^{-3}
(deliberate)	Pu	3.24×10^{4}	.14
	Am	5.84×10^{3}	.26
		Total	0.653

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8. DISCUSSION OF COMMENTS SUBMITTED BY CARL JOHNSON, M.D., DIRECTOR OF HEALTH, JEFFERSON COUNTY, COLORADO

8.1 Introduction

Dr. Carl Johnson has, during the last several years, proposed and strongly advocated use of a soil sampling and analysis procedure which supposedly gives a better indication of the inhalation hazard to persons in the vicinity of environmental transuranium element contamination then other commonly used methods.

The method proposed by Dr. Johnson requires collection of the loose surface soils with a broom and dustpan, followed by a size separation procedure, and retention of only that fraction of all particles with mass less than that equivalent to a 5 micrometer sphere of PuO_2. Results are reported in terms of activity per gram of the material analyzed.

Dr. Johnson has also published and widely diseminated certain other conclusions related to the health risk as derived from these measurements. A copy of a paper prepared by Dr. Johnson, which summarizes most of his pertinent views, is appended. The staff of the Office of Radiation Programs has reviewed these submittals and its conclusions are presented in this section.

8.2 Applicability of Soil Sampling Methods

The usefulness of any soil sampling method to indicate the potential inhalation hazard to individuals is questionable because the correlation of air and soil concentration must be made by calculational models which require certain specific information applicable to the particular site. The limited accuracy, precision, and reproduciblity of environmental measurements necessarily introduces some uncertainty into such calculations. The relationship of a soil concentration per unit area to an air concentration per unit volume is generally given by a resuspension factor, defined as

$$RF = \frac{\text{air concentration/m}^3}{\text{soil concentration/m}^2}$$

Observed values of the resuspension factor for environmental contamination existing for more than a few years are generally between 10^{-9} and 10^{-11}/m. However, before a resuspension factor can be applied to a site, it must be derived from a statistically significant number of measurements for that specific site. This may be difficult because soil concentrations can vary greatly from sampling location to sampling locations, and only a fraction of the particulate content of the air is derived from the soils in the immediate vicinity of the sampling location.

More general methods based on the mass loading of suspended particulates in air, usually derived on a regional basis, have also been suggested and appear to give a much better indication of the time averaged air concentration at a specific location. However, in all cases it must be recognized that soil concentration measurements are a secondary method for estimating airborne particulate concentrations and their success is directly related to the amount and quality of data available to make the proper conversion.

Despite the difficulties noted above, Dr. Johnson has chosen to use soil concentration data as the primary index for evaluating potential inhalation exposures. Therefore, the questions which must be addressed are whether the proposed sampling and analysis technique has general validity, how it compares to other methods, what the significance of the differences represents in terms of public health protection, and whether Dr. Johnson uses his data correctly in determining the inhalation hazard to individuals. These points will be considered in turn.

8.3 Inhalation Hazard

The inhalation hazard of airborne particulates is directly related to the concentration of particles in the air near ground level. The mechanism of transport to the different compartments of the respiratory system, deposition, and retention has been extensively studied. The Task Group on Lung Dynamics of the International Commission on Radiological Protection published a report (J. Health Physics, Vol.12, pp. 173-207, 1966) which specifically considered lung deposition and retention in terms of an activity median aerodynamic diameter (AMAD) of particles as a basis for lung dosimetry. These models require knowledge of the amount of radioactivity associated with all sizes of airborne particles, and not of only a selected fraction. Both the concentration and particle size distribution in air are best determined by air sampling devices specifically designed for that purpose. These data then provide the input for calculation of the inhalation dose rate to persons and evaluation of the potential inhalation hazard.

The sampling and analysis method proposed by Dr. Johnson does not accurately measure the entire spectrum of particle sizes as actually found in the environment by including only a portion of all particles in the reported results. Therefore, the distribution as derived by Dr. Johnson's method does not provide all the data required as input by the mathematical models for dose calculation to the lung. The results from the method proposed by Dr. Johnson therefore cannot be used for the evaluation of an inhalation hazard by the standard methods.

8.4 Effect of Analysis Procedure on Particle Size Distribution

The chemical analysis procedure proposed by Dr. Johnson is designed to alter the size distribution of the samples collected in the environment. It achieves this result by subjecting the soil particles to various chemical and physical dispersion methods which break down the bonding forces which hold the microaggregates together. The peroxide treatment removes the organic matter which serves as a binding component, and the ultrasonic treatment separates and disperses the particles. As a result, the distribution after treatment tends to have many more particles in the smaller size range and therefore to indicate a larger fraction of the total plutonium to be associated with particles in the "respirable size" range.

The effect of the treatment used by Dr. Johnson differs with the type of soil. For the soils in the vicinity of the Rocky Flats Plant, it has been shown (Tamura in Transuranics in Desert Ecosystems, Report of the Nevada Applied Ecology Group, U. S. Dept. of Energy, NVO-181, Nov. 1977) that the dispersive treatment reduced the particle size from an initial distribution where less than 60% of the activity was associated with the "respirable range" of particles to a point where more than 90% of the activity was in that range. The activity median aerodynamic diameter was changed from 43 um for the untreated soil to 1.6 um for the hydrogen peroxide treated - ultrasonically dispersed soil.

It must be concluded that the analysis method used by Dr. Johnson drastically alters the size distribution of the soil samples and does not accurately reflect the fraction of radioactivity associated with soil particles in the "respirable size" range.

8.5 Particle Sizes and Inhalation

The method proposed by Dr. Johnson involves measurement of particle size by a standard water-sedimentation technique commonly used by soil scientists. The diameter determined by this technique is referred to as the Stokes diameter, and is derived from the settling velocity and density. However, it is the aerodynamic diameter (D_a) rather than the Stokes diameter (D_s) which is generally used in models which have been developed to describe the deposition and retention of inhaled particles in the evaluation of an inhalation hazard. This aerodynamic diameter, defined as the diameter of a unit density sphere having the same terminal velocity as the particle in question, takes into account the variable linear dimensions, density, and aerodynamic drag factors which may vary considerably from particle to particle. The Task Group on Lung Dynamics of the International Commission on Radiological Protection has recommended use of the aerodynamic diameter in assessing inhalation hazards.

For the same terminal velocity of a particle, the Stokes diameter and the aerodynamic diameter can be related by

$$\sqrt{\rho} D_s = D_a$$

that is, the aerodynamic diameter is larger than the Stokes diameter by a factor equivalent to the square root of the density. For PuO_2 particle with a density of 11.4g/cm^3, this factor is 3.4.

Therefore, the 5 um particle as measured by water sedimentation referred to by Dr. Johnson actually is a particle with a 16.9 um aerodynamic diameter. Because particles with aerodynamic diameters exceeding 10 um are completely removed from the incoming air as it passes through the nose, and do not penetrate to the lung, the proposed method may greatly overestimate the respirable component of soils.

8.6 Comparison of Results Obtained by Different Methods

Significant differences exist in results of measurements of soil concentration for the same area when reported by Dr. Johnson as compared to results obtained by other methods, and it is important to recognize the reason for these differences. It is reasonably well established that most environmental contamination by transurium elements, whether derived from fallout or more localized sources, is associated primarily with the smaller soil particles near the surface. Therefore, all methods - including the method proposed by Dr. Johnson - will give approximately the same results when these are reported in terms of activity per unit area. Significant differences are, however, introduced when the results are reported in terms of activity per unit weight or mass because the basis for comparison then is a function of the specific sampling procedure. Methods which collect a greater amount of soil per unit of surface area, such as those which include all material to a given depth, then will give a smaller activity per unit weight (e.g. curies per gram) than those which limit the amount of soil included in the analysis by either sampling to a smaller depth or by eliminating a portion of the entire sample by size fractionation. Because of the much higher activity to mass ratio in the size fraction sampled by Dr. Johnson, that method will generally give higher numerical results. It is important that the reasons for these differences be understood and should be noted that these differences do not represent real differences in the environment. It is very important, therefore, that the exact method used be specified and to recognize that the results obtained by different methods cannot be used interchangably.

8.7 Dust Inhalation and Lung Dose

A large portion of Dr. Johnson's discussion is directed toward the probability of inhaling a plutonium particle. The issue, however, is what is the dose/effect of that particle when it is inhaled - regardless of the probability of inhaling it.

Dr. Johnson erroneously assumes that a resuspended 5 um particle will consist solely of PuO_2 and proceeds to calculate the mass and activity of this particle based upon the specific activity and density of PuO_2. Dr. Johnson's assumption will considerably overestimate the activity associated with a particle of a given size, because most resuspended particles consist of a large soil particle with a smaller plutonium particle associated with it. Hayden (in "Atmosphere - Surface Exchange of Particulate and Gaseous Pollutants", ERDA CONF-740921, 1974) measured the sizes of plutonium particles associated with soil particles at Rocky Flats and found the PuO_2 particles to have a median diameter of approximately 0.08 um. This is consistent with a report by Little and Whicker (Journal of Health Physics, Vol. 34, pp. 451-7, May 1978) which states that the contaminated oil at Rocky Flats was reportedly drained through 2-3 um filters before placement into barrels.

Dr. Johnson greatly overestimates the amount of soil inhaled, when he states that an individual may inhale and retain as much as 10 to 12 grams of dust in the lung over the course of a few months. Airborne particulate mass loadings at rural sites, as reported by the National Air Surveillance Network average on an annual basis between 10 to 50 ug/m^3. The amount of dust inhaled by an individual can be calculated from this mass loading. For an assumed dust leading of 50 ug/m^3 (the average for Colorado is much lower) and a breathing rate of 20 m^3/day, less than 0.4 g/yr would be inhaled by a person living near Rocky Flats.

Krey (CONF-740921, ibid) has measured the activity per gram of respirable dust in the vicinity of Rocky Flats and found the concentration to be approximately 5 dpm/g. Based upon a 0.4 g/yr inhalation rate, an individual would therefore inhale 2 dpm each year or 0.9 pCi/yr. It can be shown that continuous inhalation of 19 pCi/yr inhaled continuously for 70 years is equivalent to a pulmonary dose rate of 1 mrad/yr (Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment, EPA-520/4-77-016). Therefore, the maximum dose rate to an individual in the area of the Rocky Flats Plant as calculated by this method would be only about 0.05 uCi/year. This calculated dose rate is lower than the Guidance recommendation limit of 1.0 millirad per year by approximately a factor of twenty .

8.8 "Distribution" Factor

The Environmental Protection Agency has recognized deficiencies in how most sampling methods are used to evaluate the contribution of the smaller particles in the soil to the inhalation hazard, and has developed a method which considers the ratio of activity to mass in different particle size ranges (termed "enrichment" or "distribution" factor). It is intended to both minimize the number of analyses required and provide a maximum of useful information. The method requires a detailed analysis of a small number of representative soil samples from a given location, the results of which can then be applied to all samples taken from that area. Most analyses can then be performed on soil samples including all size fractions (generally all particles smaller than 2 millimeters - the definition of agronomic soil) while site-specific information can be derived on the composition of the resuspended portion. The method is intended to be used with the mass loading calculational procedure for deriving the corresponding air concentration, rather than with the resuspension method which already includes the correction term in the experimental data. In effect, the "enrichment" or "distribution" factor converts the average radioactivity to mass radio for the entire soil sample to the radioactivity to mass ratio of only the resuspended fraction. Details of the method are described in EPA document 520/4-77-016 entitled "Proposed Guidance on Dose Limits for Person Exposed to Transuranium Elements in the General Environment."

8.9 Conclusion

In summary, the U. S. Environmental Protection Agency does not recommend that soil sampling and analysis methods be used as the primary means of implementing requirements which specify inhalation dose limits to members of the general population. Such methods suffer from the inherent problem of relating the soil and air concentrations of the contamination and, at best, can only serve as a useful indicator or screening tool. The results obtained by the different methods for soil sampling and analysis are not generally comparable, and must be specified in terms of the procedures used.

Any of the commonly used, or proposed, soil sampling and analysis methods can be utilized for evaluation studies and provide useful data. Application to implementation of public health protection criteria of any soil sampling method is limited by the fact that environmental pathway and transfer factors must be determined on a site-specific basis and validated with extensive experimental data. The usefulness and confidence one can place in the results obtained by any particular method is therefore directly related to the extent that the method furnishes reliable data useful for the estimation of adverse health impacts on individuals in the general population.

In the view of the Agency staff, the method proposed by Dr. Johnson does not satisfy technically acceptable criteria for adequate evaluation of a potential health hazard to individuals or population groups. It does not provide the required data for calculation of lung dose rates by methods recommended by the International Commission on Radiological Protection, incorrectly classifies the sizes of particles with respect to inhalation dynamics, and greatly overestimates the intake of respirable dusts by an individual. We therefore conclude that the proposed method should not be used to assess the inhalation hazard to individuals living in close proximity to environmental contamination.

EVALUATION OF THE HAZARD TO RESIDENTS OF AREAS CONTAMINATED WITH PLUTONIUM

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Abstract

Plutonium oxide particles in the fine particulate soil fraction of surface dust are subject to suspension by air currents and are a potential health hazard to humans because of inhalation. This respirable particulate fraction has been defined as the particles ≤ 5μm. The respirable fraction of surface dust can be separated by ultrasonic dispersion and a standard water-sedimentation procedure. We believe this method of evaluation defines more precisely the potential health hazard from plutonium-contaminated soils than other methods. With this method, plutonium levels in the respirable-particulate fraction of offsite soils located downwind from a plutonium-processing plant (Rocky Flats) were found to be as much as 380 times the background level. Risk estimates for residents may be made by calculation of dosage related to quantities of respirable dust inhaled annually. For example, in residential areas with 20 disintegrations of plutonium per minute per gram of respirable dust, a person may inhale and retain 10 to 12 grams or more of resuspended dust (100 picocuries) over a period of months or years and may receive about 0.1 rem to the lung, 4-5 rem to the trachio-bronchial lymph nodes, and 0.12 rem to the liver. The gonadal and fetal dose is difficult to evaluate, but plutonium has been found in gonadal tissue and in the fetus. This amount of exposure to one million people could result in about 160 excess deaths due to leukemia and a total increase in all neoplasms of perhaps 1 to 3 per cent over a period of 70 years. This may include from 6 to 1000 excess cases of bone cancer (this large range is due to two points of view). The incidence of all genetic diseases may increase by 1.5% and ill health related to chromosome mutation by 10%, for all succeeding generations. Other factors, such as the ingrowth of Americium, use of chelating agents in fertilizers, etc. may change the nature of the risk and actually increase the incidence of effects. These considerations demonstrate a need for the establishment of conservative limits on permissable soil contamination by plutonium in residential areas.

Introduction

Plutonium oxide particles deposited on the ground surface by accidental spills or atmospheric fallout (Table 1) are subject to resuspension by wind or other means. Particles in the size range of 5 μm and smaller are considered to be of respirable size because when inhaled they may be retained within the lung(1). Most of the plutonium oxide particles released offsite by nuclear installations are in this size range(2). This paper describes a method of measuring the concentration of plutonium in the potentially respirable surface dust and discusses the potential health effects of exposure to such dust.

Sample collection and processing

In our study area (downwind from the Rocky Flats plant) sites for sampling were selected following guidelines proposed by the Atomic Energy Commission(3). A composite sample of the loose, surficial (about 0-0.5 cm deep) soil material was collected with a clean brush and a clean plastic container within an area of 4 m^2 when the ground surface was dry(4). Plutonium oxide particles likely exist in association with other soil particles as micro-aggregates and, therefore, behave as such. Microaggregates of soil are dynamic and are affected by freezing and thawing, wetting and drying, the kind and amount of natural cementing agents present, and by other forces that tend to disrupt or reconstitute them(5). These plutonium-oxide-microaggregate associations cannot be measured except by methods that tend to alter their natural state. In contrast, our procedure seeks to maximize the dispersion of the microaggregates to expose the plutonium oxide particles and to evaluate the maximum potential hazard. Attention to the dispersion of microaggregates will tend to alleviate the problem of the effect of microaggregation on the precision of the data and will provide data that are comparable from season to season or from site to site.

About 50 g of soil material that passed a 2-mm screen was treated by standard methods with hydrogen peroxide to remove organic material. The sample was then washed and filtered to remove soluble salts, and was mechanically dispersed with a 300 watt ultrasonic probe for 15 minutes. Sodium metaphosphate was added when necessary to facilitate dispersion of the particles.

Particles of respirable size were separated by size and density with a standard water-sedimentation technique(6). The threshold settling velocity was computed from Stoke's equation using an effective diameter of 5 μm and a density of 11.36 g/cm^3 (plutonium oxide). The size fraction thus collected includes other mineral particles with equivalent settling velocities that have some combination of smaller density and larger diameter. The collected fraction was freeze-dried and analyzed for plutonium by radiochemical procedures(7,8). Contamination of offsite soils in the study area (an area proposed for residential development) was found to be as great as 380 times the background value. We believe that the concentration of plutonium in the respirable fraction of surface dust, as defined here, is an index that can be more readily related to the potential health hazard than other indices utilized for this purpose.

Particle Size and Activity

Relationships between particle size, volume, mass and radioactivity are shown in Table 2. A particle of plutonium oxide one μm in diameter weighs about six millionths of a microgram (μg). This particle is very small but has an activity of 0.3 picocuries (pCi) or about one disintegration every 1.5 minutes. A particle 5 μm in size has a mass of .007 μg. This particle is also of respirable size and will have an activity of about 41 pCi or some 90 disintegrations per minute (dpm). One hundred of the 5 μm particles together would weigh about 0.07 μg. Since plutonium has a biological activity 15 or more times as great as radium, this many particles of plutonium oxide may be similar in effect to 0.5 μg of radium, the smallest bone dose found associated with osteosarcoma in radium dial painters(9). Although plutonium may be present in contaminated areas offsite in extremely small quantities, this may be sufficient to produce bone cancer and other types of tumors.

Estimates of Dosage and Effect

The recommended dose limit of plutonium 239 (occupational exposure) to lung is at present 15 rem/year or 16,000 pCi. This maximum permissable annual dose (MPAD) is equivalent to about 400 five μm particles, or a total mass of about 0.3 μg of plutonium oxide. A single particle of plutonium oxide 40 μm in size has more than this much activity and is within the range of atmospheric dust (0.3 to 100 μm). A particle of this size might not be retained in the respiratory tract, but could lodge in an abrasion or other wound.

Meyers gives evidence to support a recommendation that a much more realistic limit than the present 15 rem MPAD for lung burden is the "maximum permissable pulmonary lymph node burden" which is placed at 230 pCi(10). The maximum lung level that could produce this is 67 pCi. Meyers points out that this is less than 0.5% of the currently accepted MPAD (occupational) of 15 rems for the lung. The inhalation and retention of two 5 μm particles annually would exceed this amount. Morgan also demonstrates that the present limit for exposure to plutonium may be too high by a factor of 240 or more, in relation to potential effects on bone(11). Again, two of the 5 μm particles would exceed this more conservative dose limit.

The relative risk of inhaling and retaining plutonium oxide particles in reference to the amount of plutonium in the respirable dust is illustrated in Table 3. A single 4 μm particle may produce about 50 dpm, equivalent to about 20 millirems. One such particle in 25 grams of respirable dust will produce an average activity of 2 dpm/gram of dust. If a person has inhaled and retained 12.5 grams of dust, he has a 50% chance of inhaling that one 5 μm particle of plutonium oxide. However, the particle may be in the first bit of dust inhaled or in the last bit. The probability is one in 100, expressed in the table as $p=.01$, that if he inhales only 1/4 gram, that he may inhale the 5 μm particle. Retention of two of these particles, or an equivalent larger number of smaller particles, would exceed dose limits proposed by Morgan and Meyers. It may be that in the very first whiff of dust (25 milligrams) that he may inhale the particle. The chances are about one in one thousand that this could occur. In a total population of 100,000 or more who could be housed in a contaminated area such as that near the Rocky Flats plant, these odds seem significant.

The effects on populations of exposure to low levels of radiation have been studied by the Advisory Committee on the Biological Effects of Radiation of the National Academy of Sciences and the National Research Council(12). The committee discusses the Federal Radiation Council's maximum permissable level of 5 rem over 30 years (170 mrem/year). This dosage, 170 mrem, is equivalent to about four of the five μm plutonium oxide particles, or to about 20 grams of respirable dust with 20 dpm/g of plutonium. The committee thinks that this level would likely result in an increase of cancer deaths by about 2%. In addition, they calculate that the effect of 170 mrems/year would cause in the first generation an increased incidence of 0.05% of serious, dominant, or x-linked diseases and defects per year. This is one birth in 2,000. However, after several generations, these numbers would be five times larger, that is, there would be one birth in 400 with defects and serious dominant, or x-linked diseases per year. In addition, the committee states that when the congenital abnormalities and constitutional diseases which are partly genetic are added to this, the total incidence would be 0.1% or one case per thousand births in the first generation, and 0.75% or about one birth in 133 for succeeding generations. The committee also believes that between 5% and 50% of ill health is proportional to the mutation rate. This much radiation per generation could eventually lead to an increase of 5% in the ill health of the population.

Estimates of excess rates of cancer may also be calculated in the following manner, again referring to an area with 20 dpm/g of plutonium in respirable dust. The following example is the calculation of the increased rate of bone cancer in such a contaminated area.

$$\frac{1\text{ rem} \times \text{one million persons}^{(13)}}{10\text{ excess bone cancer cases}} \cdot \frac{1000\text{ pCi (inhaled)}^{(14)}}{3.2\text{ rem (bone)}} \cdot \frac{2.2\text{ dpm}}{1\text{ pCi}} \cdot \frac{1\text{ gram}}{20\text{ dpm}} = \frac{3.4\text{ grams dust}}{1\text{ excess bone cancer per million persons}}$$

Offsite lands in our study area (downwind from the Rocky Flats plant) have levels far in excess of this amount, and a development project five kilometers east of the plant site has levels that approach 20 dpm/g in respirable dust. We see that about 3.4 grams of such dust (32 pCi), inhaled and retained, may result in one excess bone cancer case in a population of one million people over a life span. Other effects from this dosage of radiation may be calculated in a similar manner. Such effects would be multiplied for each additional 3-4 grams of respirable dust inhaled*. Over a period of months or years a person may inhale and retain 10 to 12 grams or more of resuspended dust (100 pCi) and may receive about 0.1 rem to the lung, 4-5 rem to the trachio-bronchial lymph nodes, and 0.12 rem to the liver. The gonadal and fetal dose is difficult to evaluate, but plutonium has been found in gonadal tissue and in the fetus. This amount of exposure to one million people could result in about 160 excess deaths due to leukemia and a total increase in all neoplasms of perhaps 1 to 3 per cent over a period of 70 years(12). This may include from 6 to 1000 excess cases of bone cancer (this large range is due to two points of view)(11, 12). The incidence of all genetic diseases may increase by 1.5% and ill health related to chromosome mutation by 10%, for all succeeding generations(12). Other factors, such as the ingrowth of Americium, use of chelating agents in fertilizers, etc. may change the nature of the risk and actually increase the incidence of effects. Because plutonium is stored in the body to a considerable extent, a person living several years in such an area may inhale and retain enough plutonium to produce these effects even though he may leave the area.

Effects are more likely to occur in the fetus, the child, and in persons with increased susceptibility to neoplasms. There is evidence that smaller doses of radiation are more harmful per rad than would be expected. Stewart and Neal and others have shown a greater risk of leukemia per rad at low intrauterine exposures, 0.25-0.5 rad, than at higher doses to the fetus(15). One rem (equivalent to 25 5μm particles) may cause an 80% increase in mortality from childhood cancers after fetal exposure, and a 0.9% increase in recognized "spontaneous" abortions(13).

Conclusion

Federal guidelines are being promulgated by the U.S. Environmental Protection Agency to guide the use, treatment, and rehabilitation of land contaminated with plutonium. At the present time there are areas in the United States which have levels of contamination of 19 dpm/g in respirable dust which are presently being used or developed for residential purposes(16). The importance of the establishment of a maximum allowable level of contamination based on the concentration of plutonium in the respirable dust must be emphasized. This level may be appropriately set as low as 2 dpm/g, since there is sufficient evidence to indicate probable health effects at the 20 dpm/g level, and possibly at levels below this figure.

As much as 67 mg of dust per cubic meter (mg/m^3) has been measured downwind from farm equipment. An average value of 0.125 mg/M^3 was observed in Denver in 1970-73. Average annual respiratory volume is about 8000 m^3 for an adult.

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Table 1

Concentrations of Plutonium in Soil

Location	Disintegrations per minute/gram
Worldwide (fallout)	0.0 to 0.4
Central New Mexico (Trinity)*	0.3 to 22.2
Nevada Test Site*	0.2 to 22.2
Los Alamos Scientific Laboratory*	0.01 to 111
Rocky Flats*	0.4 to 211
Bikini Atoll	2.9 to 422
Palomares	0 to 3996
Eniwetok Atoll	76 to 7104

*Offsite Adapted from Ref. 17

Table 2

Plutonium oxide particles: Volume in cubic micrometers (μm^3) mass in micrograms (μg) and radioactivity of plutonium 239 in picocuries (pCi) and disintegrations per minute (dpm) by particle size in μms, for sphere-shaped particles.

Particle size in μm	Volume μm^3	Mass μg	Activity pCi	Activity dpm
40	33,510	0.38	21,000	46,000
5	61	0.7×10^{-3}	41	90
4	34	3.8×10^{-4}	21	46
2	4.2	4.9×10^{-5}	2.6	5.8
1	0.5	6.1×10^{-6}	0.3	0.7

Table 3

Relative risk of inhaling and retaining plutonium particles, by level of radioactivity of respirable dust and quantity of contaminated dust inhaled.

Activity of plutonium in respirable dust	Assuming one particle, grams dust inhaled and retained to retain 50 dpm* p=.5	p=.01	p=.001
2 dpm/g	12.5	0.25	0.025
5 dpm/g	5	0.10	0.01
10 dpm/g	2.5	0.05	0.005
20 dpm/g	1.2	0.02	0.002

* 50 dpm may be produced by one particle about 4 μm in diameter, and is equivalent to about 20 millirems.

Table 4

Dose-equivalent in rem per 1000 picocuries of plutonium 239 inhaled.

Organ	Plutonium 239
Lung*	0.9
Lymph Node*	43.7
Bone	3.2
Liver	1.3
Kidney	0.2
Gonads	0.05

* Assumes that particles are retained for a longer period of time in the lung. (Adapted from Ref. 18)

Table 5

Estimated rates of plutonium-induced cancer and hereditary injury per million persons-rems

Prediction based on data from:	Neoplasm Lung	Neoplasm Bone	Hereditary Injury
Man*	16-110	2-17	50**
Dog	70	70	
Rat	60(700***)	10	
Mouse		20	

* BEIR Report (also 1-7 cases of liver cancer per million person-rems)

** 50 cases per million person-rems for immediate family, 300 cases for all generations and a maximum of 600 for defects of complex origin. The expected increase in hereditary injury is about 1% per rem for five major and different indices of genetic effect.

*** 238 Pu (Adapted from Ref. 14)

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Enclosure II

DEPARTMENT OF ENERGY
COMMENTS ON DECONTAMINATION COSTS DISCUSSED IN THE EPA PROPOSED GUIDANCE ON DOSE LIMITS FOR PERSONS EXPOSED TO TRANSURANIUM ELEMENTS IN THE GENERAL ENVIRONMENT

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ESTIMATE OF POTENTIAL COSTS OF HYPOTHETICAL CONTAMINATING EVENTS

I. APPROACH

In processing, transporting, and using transuranic materials, stringent measures are taken to prevent accidental releases of the materials to the environment. Should accidents occur, similar rigorous attention would be paid to minimizing risks and injuries to people and property in or concerned with the affected geographic areas. Nevertheless, it is reasonable to examine the potential effects that application of the proposed Guidance might have on the costs and on the economic and ecological impacts associated with decontamination procedures.

For purposes of conducting such an analysis, hypothetical accidental releases of transuranic materials were assumed to have occurred at each of three real, but not identified, sites in the United States. (See Appendix A for descriptions of these sites.) The analysis was based on the alternative assumptions that 1-km2 and 10-km2 areas were found after the hypothetical contaminating events to require remedial treatment under the proposed Guidance. Cost estimates included expenses expected to be incurred in the conduct of an appropriate sampling program (described in Appendix B). The sampling program would be needed to define these areas, determine the types of treatment required, and assess the effectiveness of these treatments after their application. Cost estimates were made in each instance for application of a variety of treatments that would be acceptable under the Guidance, including:

- In-place stabilization by the application of a relatively impermeable cover and by limiting area access and use
- Dilution by plowing or other similar techniques
- Disposal by removal of surface soils and burial either onsite or in a designated waste storage repository.

Application of these treatments was assumed to be accomplished through a series of steps appropriate to the conditions at the sites (see Appendix C).

Costs for cleanup and for long-term stabilization and access-restriction alternatives were calculated by estimating unit costs for all critical components (Appendix D), then applying these costs to the specific circumstances at the respective sites. Activities assumed, for purposes of cost estimating, to be involved in the treatment of contaminated areas included initial sampling and monitoring to locate and assess the degree of contaminated soils and materials; population evacuation, maintenance, and radiological monitoring; plowing or removal of contaminated vegetation and soils, and cleaning of structures; temporary storage of contaminated materials; packaging, transport, and permanent disposal of contaminated materials; post-cleanup monitoring; and restricted area maintenance. In addition to direct treatment costs, estimates of costs from the interruption of economic activities were also made.

The analysis of costs and economic impacts is presented as the main body of this report because the estimates of these impacts appear to be the most significant results of the study. All other material that supports the analysis of cost and economic impacts follows in Appendices A-D. Also included is Appendix E, which presents a general description of probable ecological impacts. Assumptions basic to the study are presented in Table 1, which appears in the Costs and Economic Impacts Section.

II. COSTS AND ECONOMIC IMPACTS

This section presents an analysis of possible costs attendant to decontamination and related activities that might be necessary following an accidental release of transuranic materials.

A number of factors would affect these costs. The equations developed in this section account for the major factors, including the size of the area affected, the length of time that the area would be affected, and the type and level of normal economic activity in the area.

GENERAL CONSIDERATIONS

The analysis of costs presented here is sensitive to a number of assumptions, exclusions, and simplifications. A list of the principal ones is provided in Table 1 for convenient reference. They are developed more fully in the text that follows.

Decontamination of areas impacted by a release of transuranic material might be accomplished under the Guidance in several ways, including site restriction, stabilization, earth removal, or dilution through plowing. Buildings and other structures would have to be handled by other techniques. The costs and effects of these methods would differ for any given situation. The decontamination of a site might be handled best by a combination of techniques applied to different portions of the total area to achieve the desired result. Since the number of potential combinations for any site would be large, however, the analyses reported here assumed use of only one treatment at a time for all relevant portions of a site. The cost estimates derived from application of the various methods on each site were then compared to suggest treatment cost ranges.

TABLE 1. Important Analytical Assumptions, Exclusions, and Simplifications

1. This study considers potential costs associated with hypothetical accidental releases of transuranic materials. It does not consider any actual contaminated sites or releases associated with routine facility operations.

2. The study does not consider effects associated with the events occurring during and immediately after the accidents; it deals only with the effects of treating the contaminated areas resulting from the accidents. Treatment is taken to include, however, both initial sampling and any necessary evacuation of people from affected areas.

3. The site descriptions were based upon real, uncontaminated areas; therefore, real land use, economic, and ecological data were used in the analyses.

4. Cleanup cost estimates were based upon the assumption that adequate dose rate reductions would be achieved on the first application of the selected treatment to each contaminated area. Not included are the costs that would be incurred if the treatment had to be repeated to reduce contamination to acceptable levels.

5. Costs for packaging, transporting, and disposing of contaminated earth removed from an area were based upon removal of soil to a depth of 5 cm.

6. Estimates derived in this study represent total costs for dealing with the accidental releases in compliance with the Guidance, rather than marginal costs representing the differences between working with and without the Guidance. The total-cost approach is consistent with the approach taken by EPA in the estimates provided in the Guidance.

7. The estimates were calculated from unit costs for materials, equipment, and labor, based upon national averages.

8. The costs of having crews and equipment idle while awaiting post cleanup sampling results were not included in the estimates.

9. Costs for shipment of decontamination equipment or crews to affected areas were not included in the estimates.

10. The population located within areas designated for treatment was assumed evacuated as a part of the treatment process. It was assumed that the average evacuation period would be 30 days.

11. No cost estimates were included to cover expenses associated with environmental impact analyses, environmental impact statements, or potential litigation arising from possible contaminating events and subsequent cleanup activities.

TABLE 1. (contd)

12. Psychological trauma and other nonquantifiable effects of treatment measures for contaminated areas were not assessed.

13. Health effects from radiological exposures or other hazards associated with treatment of contaminated areas were not estimated.

The Guidance specifies that remedial treatment of contaminated areas would be necessary wherever the dose rate to individuals residing in the affected areas would exceed 1 mrad/yr to the pulmonary lung or 3 mrad/yr to the bone. The Guidance also indicates that areas in which the transuranic contamination in the top cm of soil did not exceed 0.2 μci/m^2 could be considered safe without remedial treatment. For purposes of the illustrative analyses conducted in this study, it was assumed that an appropriate sampling program (for which costs were included) had led to the delineation of areas requiring remedial treatment, based upon these criteria. Costs and ecological effects estimated for each of the three reference sites considered were based on the alternative assumptions that the sizes of the areas requiring treatment were 1 km^2 or 10 km^2.

The costs of remedial treatment of contaminated sites would be dependent upon factors heavily influenced by either area size or the time required to effect the treatment. The main cost elements that would be more affected by time than by area are the possible costs of evacuation and production loss. While initial evacuation costs may be thought of as an independent factor, the costs to the population during decontamination would be directly dependent on the length of time involved. The monetary loss experienced by nonagricultural workers, for instance, would depend largely on the amount of time these workers were prevented from working. Agricultural production losses would depend on the time required to bring land back into production at a level equal to that prior to contamination. These losses were estimated here on the basis of average production levels and product values. The actual losses from a real accident would vary greatly from site to site and from one commercial activity to another within sites.

The cost calculations presented here were formulated on the basis of estimated average costs for wages, materials, equipment, evacuation expenses, etc., required to treat each km^2 of affected land of a given type or use. While one might prefer for the sake of greater accuracy to apply scale economy and marginal cost principles, their use would necessitate firm assumptions on cleanup timing and on equipment and labor availability in the affected area at the specific time they were needed. Unless consistent for all cases studied, these assumptions would detract from the usefulness of the analyses of various cases for comparative purposes. It is not expected that the error in cost estimates resulting from the exclusion of scale economy and marginal cost principles was unacceptably large, given the purposes of the analysis and other necessary assumptions, exclusions, and simplifications that affected the results.

COST ESTIMATION FRAMEWORK

Once areas and contamination levels in a situation have been identified and treatment techniques chosen, the total costs of decontamination of an area may be estimated by the cost equation:

$$TC_1 = ET \sum_{n=1}^{n} K_n P + M \sum_{n=1}^{n} K_n P + S + Q$$

(Total Cost) = (Evacuation) + (Population Monitoring & Decontamination) + (Site Survey & Sampling) + (Surveillance)

$$+ \sum_{n=1}^{n} K_n A_n + DK_e + FK_e$$

+ (Decontamination) + (Temporary Burial) + (Final Burial)

$$+ \sum_{r=1}^{r} K_r L_r + \sum_{u=1}^{u} K_u L_u + X_1 \sum_{r=1}^{r} K_r T$$

+ (Rural Land Reclamation) + (Urban Land Reclamation) + (Agricultural Production Loss)

$$+ (X_2 + X_3) \sum_{n=1}^{n} K_n PT$$

+ (Manufacturing & Other Production Loss) where:

TC_1 = Total cost of decontamination-related activities and compensation

E = Evacuation cost per capita per day

M = Cost per capita for population monitoring and decontamination

S = Cost of preliminary site survey and sampling

P = Population per km^2

Q = Cost of surveillance

T = Estimated time to complete decontamination

K = Land area in km^2

n = Number of land areas to which a unique set of decontamination procedures is applied

r = Rural

u = Urban

K_e = Area in km^2 where earth removal is used

A = The cost per km^2 of each unique set of decontamination procedures (labor, machinery and supplies)

L = Land reclamation costs per km^2

D = Temporary burial site costs per km^2 (stabilization plus monitoring costs)

F = Cost of final disposal per km^2

X_1, X_2 and X_3 = Production losses (agricultural, manufacturing and other in that order).

In cases where the total decontamination costs were found to exceed the estimated value of the area, stabilization of the contaminant and restriction of the site might be desirable. If so, the following cost equation would be appropriate to estimate total cost:

$$TC_2 = ET\,K_tP + MK_tP + S + Q$$

$$\text{Total Cost} = (\text{Evacuation}) + \begin{pmatrix}\text{Population}\\ \text{Monitoring \&}\\ \text{Decontamination}\end{pmatrix} + \begin{pmatrix}\text{Site Survey}\\ \text{\& Sampling}\end{pmatrix} + (\text{Surveillance})$$

$$+ RK_tP + (Z + Y + V)K_t$$

$$+ \begin{pmatrix}\text{Population}\\ \text{Relocation}\end{pmatrix} + \begin{pmatrix}\text{Site Purchase,}\\ \text{Stabilization \&}\\ \text{Surveillance}\end{pmatrix}$$

where:

TC_2 = Total cost of site-restriction-related activities and compensation

E = Cost of evacuation per capita

M = Cost of population monitoring and decontamination per capita

S = Cost of preliminary site survey and sampling

Q = Cost of surveillance

K_t = Total area to be restricted in km^2

T = Time until decision is made to relocate the population

P = Population per km^2

R = Per capita relocation costs including compensation for production losses

Z = Condemnation value of site and buffer zone per km^2

Y = Cost of site stabilization per km^2

V = Present value per km^2 of site surveillance.

Where a situation dictated restriction of part of the area and decontamination of the remainder, the two cost equations could be applied to the appropriate portions of the total area and summed to estimate total cost.

COST DATA

Using the treatment measures assumed to be applied to the sites of hypothetical transuranic contamination, point estimates were found for the costs incurred from the time of the accident until the land was restored to its original use and disposal of the transuranic wastes was complete. The unit costs (including overhead) given in Table 2 were used to compute the site cost estimates. A discussion of the procedures used to determine these unit costs is presented in Appendix D.

In order to find the cost of the set of procedures called for in the decontamination of a given land type, the land area in one use (K_n), shown in Table 3, was multiplied by the sum of appropriate procedure unit costs (A_n) from Table 2. Examples of the estimated costs of decontamination procedures (in 1977 dollars for earth removal, not including reclamation) for various land types are as follows:

Forests	\$561,500/km^2
Cornfields	\$423,000/km^2
Plowed Farmland	\$403,000/km^2
Pasture	\$403,000/km^2
Residential Area	\$611,000/km^2
Industrial Area	\$897,000/km^2

To derive the cost of decontaminating commercial and residential areas, some assumptions on the composition of these areas were made, as presented in Table 4. The production-loss and real estate values used are given there also. While production losses and real estate values for agriculture would depend on the land area affected by the contamination, commercial production losses and commercial real estate values would depend both on the population employed and on capital investment. Since capital investment data are not readily available, however, the cost estimates here were computed on a per capita basis.

From the unit costs and assumptions regarding land use, costs were estimated for all aspects of decontaminating and managing each site. These are given in Tables 5 through 7, using earth removal on the contaminated soil areas. The total cost for each site is rounded to the nearest \$100,000.

TABLE 2. Unit Costs for Area Decontamination and Management

	Cost ($ 1977)	Cost Plus Burden
Two Weeks of Water Fixation	$ 44,500/km^2	$ 73,500/km^2
Long-Acting Stabilizer	62,500/km^2	103,500/km^2
Corn Removal	12,000/km^2	20,000/km^2
Other Crop Removal	2,500/km^2	4,000/km^2
Earth Removal (Grader)	137,000/km^2	226,000/km^2
Earth Removal (Front-End Loader)	250,000/km^2	412,500/km^2
Earth Removal (Manual Labor)	430,500/km^2	710,500/km^2
Field Sod Removal	137,000/km^2	226,000/km^2
Lawn Sod Removal	171,000/km^2	282,000/km^2
Vacuumized Sweeper	24,000/km^2	40,000/km^2
Fire Hosing	30,000/km2	50,000/km^2
Homes	200/home	350/home
Population Monitoring & Decontamination	300/person	---
Evacuation, Including Room, Board, Transportation and Personnel(2, p. 12-3)	15.00/person/day	---
Lawn Resodding	945,000/km^2	1,275,500/km^2
Topsoil Replacement	1,183,500/km^2	1,597,500/km^2
Erosion Control	154,500/km^2	208,500/km^2
Fertilizer + Seed (Materials Only)	48,500/km^2	65,000/km^2
Temporary Storage Sites (Except Land Cost)	2,000/km^2	3,500/km^2
Plowing		
25 cm	2,000/km^2	3,500/km^2
1 m, Tilled Land	21,000/km^2	34,500/km^2
1 m, Pasture, Including Reseeding(1, p. 12-11)	91,000/km^2	150,000/km^2
Surveillance (Based on Perimeter Length)	3,500/km	6,000/km
Commercial Areas	543,500/km^2	897,000/km^2
Disposal (1000 Miles of Transportation, 2-in. Soil Removal, Federal Disposal Site)		119,200,000/km^2
Biobarrier (Labor and Materials)	10,752,500/km^2	17,742,000/km^2
Fence (Based on Perimeter Length)	35,000/km	47,000/km
Present Value of Future Surveillance	100,000/km	---

NOTE: Burdened costs include overhead (25%), loss of efficiency due to protective clothing (30%), workmen's compensation and social security (10%), except for land reclamation costs which do not require protective clothing and include only overhead and social security. All unit costs are rounded to the nearest $500.

TABLE 3. Land-Type Breakdown by Site for 1.0-km^2 and 10.0-km^2 Areas[a]

	1.0 km^2	10.0 km^2
Reference Site One		
Corn Fields	0.37 km^2	3.70 km^2
Plowed Farmland	0.25	2.50
Hay and Soybeans	0.13	1.30
Pasture Land	0.11	0.60
Residential Area	5 Homes	1.40
Woodlots	0.09	0.30
Industrial Areas	0.05	0.20
Population	15 Persons	5475 Persons
Perimeter	2.5 km	15.1 km
Reference Site Two		
Forest	0.21 km^2	3.96 km^2
Shoreline	0.22	3.96
Residential Area	0.57	2.08
Population	2269 Persons	8202 Persons
Perimeter	2.5 km	15.1 km
Reference Site Three		
Pasture Land	0.58 km^2	5.80 km^2
Field Crops	0.31	3.17
Orchards	0.07	0.70
Ditches	0.03	0.30
Residential Area	0.01	0.03
Population	39 Persons	120 Persons
Perimeter	2.5 km	15.1 km

[a] Since these sites are real, the mix of land types and the land uses varies with area size; therefore, the composition of the 10.0-km^2 area at each site is not necessarily proportional to the composition of the 1.0-km^2 area.

TABLE 4. Assumed Values for Derivation of Decontamination Costs

Average annual value of production of agricultural land per km^2 = $24,000. This figure was computed from the value of cash receipts plus home consumption for U.S. farmland given in the 1976 U.S. Agricultural Statistics(3) and adjusted to 1977 dollars. A 2-yr loss of production is assumed for earth removal and plowing to 3 ft.

Median value of a single-family dwelling = $40,000. This figure was taken from a 1976 study by the MIT-Harvard Joint Center for Urban Studies and adjusted to 1977 dollars.

Value of commercial land and structures = $5,000 per capita. This figure was computed from a National Bureau of Economic Research publication(4) and adjusted to 1977 dollars.

Average value of agricultural land and buildings per km^2 = $148,000. This figure was taken from the 1974 Census of Agriculture(5) and adjusted to 1977 dollars.

Manufacturing production loss = $250 value added per capita per month. From the City and County Data Book of 1972,(6) adjusted to 1977 dollars.

Other production loss = $300 per capita per month. This figure was taken from the 1970 Census of Population(7) information on earned incomes, adjusted to 1977 dollars.

Decontamination procedure period = 1 year.

Evacuation period = 30 days.

Composition of residential areas: (taken from WASH-1400)(1, p. 12-12)

57% lawn and fields 20% pavement 23% home and roofs

Composition of Commercial areas: (taken from WASH-1400)(1, p. 12-5)

50% building 50% pavement

Relocation costs per capita = $3,500. This cost was taken from WASH-1400, (Ref. 1, p. 12-5) adjusted to 1977 dollars.

Final disposal costs are computed on the basis of figures given in BNWL-2210.(8) Tri-State Motor Transit Company,(9) and GESMO(10). The transportation distance is assumed to be 1000 miles (1609 km) for all sites.

Residences per km^2 = 1235 and persons per residence = 3.2. These figures, assumed for the site of each accident scenario, correspond to the medium-density residential pattern described in WASH-1400.(1, p. 12-4)

TABLE 5. Reference Site One: Decontamination Costs for Earth Removal for Areas of 1.0 km^2 and 10.0 km^2

Cost Element	Description	Costs ($ 1977) 1.0 km^2	Costs ($ 1977) 10.0 km^2
$ET \sum_{n=1}^{n} K_n P$	Evacuation	$ 6,800	$ 2,463,800
$M \sum_{n=1}^{n} K_n P$	Population Monitoring and Decontamination	4,500	1,642,500
S	Survey and Samples	161,500	1,069,200
Q	Surveillance	15,000	90,600
$\sum_{n=1}^{n} K_n A_h$	Decontamination:		
	Corn Fields	156,500	1,565,100
	Plowed Farmland	100,800	1,007,500
	Hay and Soybeans	52,900	529,100
	Pasture	44,300	241,800
	Woodlots	50,500	168,500
	Residential Areas	1,800	855,400
	Industrial Areas	44,900	269,100
DK_e	Temporary Storage	3,300	32,200
FK_e	Permanent Disposal	113,240,000	1,096,640,000
$\sum_{r=1}^{r} K_r L_r$	Land Reclamation	1,616,500	16,039,900
$\sum_{u=1}^{u} K_u L_u$	Lawn Resodding	--	1,020,400
	Production Losses:		
$X_1 \sum_{r=1}^{r} K_r T$	Agricultural	45,600	403,200
$X_2 \sum_{n=1}^{n} K_n PT$	Manufacturing	3,800	1,368,800
$X_3 \sum_{n=1}^{n} K_n PT$	Other	4,500	1,642,500
TC	Total Cost	115,600,000	1,127,000,000

NOTE: Total cost is rounded to the nearest $100,000.

TABLE 6. Reference Site Two: Decontamination Costs for Earth Removal for Areas of 1.0 km^2 and 1.0 km^2

Cost Element	Description	Costs ($ 1977)	
		1.0 km^2	10.0 km^2
$ET \sum_{n=1}^{n} K_nP$	Evacuation	$ 1,021,100	$ 3,690,900
$M \sum_{n=1}^{n} K_nP$	Population Monitoring and Decontamination	680,700	2,460,600
S	Survey and Samples	395,800	1,361,300
Q	Surveillance	15,000	90,600
$\sum_{n=1}^{n} K_nA_n$	Decontamination:		
	Forest	117,900	2,223,500
	Shoreline	135,800	2,444,800
	Residential Area	348,300	1,270,900
DK_e	Temporary Storage	2,600	31,900
FK_e	Permanent Disposal	89,400,000	1,084,720,000
$\sum_{r=1}^{r} K_rL_r$	Land Reclamation	43,800	825,700
$\sum_{u=1}^{u} K_uL_u$	Lawn Resodding	414,400	1,512,200
	Production Losses:		
$X_3 \sum_{n=1}^{n} K_nPT$	Other	680,700	2,460,600
TC	Total Cost	93,300,000	1,103,100,000

NOTE: Total cost is rounded to the nearest $100,000.

TABLE 7. Reference Site Three: Decontamination Costs for Earth Removal for Areas of 1.0 km^2 and 10.0 km^2

Cost Element	Description	Costs ($ 1977)	
		1.0 km^2	10.0 km^2
$ET \sum_{n=1}^{n} K_n P$	Evacuation	$ 17,600	$ 54,000
$M \sum_{n=1}^{n} K_n P$	Population Monitoring and Decontamination	11,700	36,000
S	Survey and Samples	164,100	517,700
Q	Surveillance	15,000	90,600
$\sum_{n=1}^{n} K_n A_n$	Decontamination:		
	Pasture Land	233,700	2,337,400
	Field Crops	126,200	1,290,300
	Orchards	41,300	413,000
	Ditches	17,700	177,000
	Residential Area	6,100	18,300
DK_e	Temporary Storage	3,500	34,900
FK_e	Permanent Disposal	118,723,200	1,189,616,000
$\sum_{r=1}^{r} K_r L_r$	Land Reclamation	1,771,500	17,841,000
$\sum_{u=1}^{u} K_u L_u$	Lawn Resodding	7,700	25,500
	Production Losses:		
$X_1 \sum_{r=1}^{r} K_r T$	Agricultural	47,500	478,600
$X_3 \sum_{n=1}^{n} K_n PT$	Other	11,700	36,000
TC	Total Cost	121,200,000	1,213,000,000

NOTE: Total cost is rounded to the nearest $100,000.

Table 8 presents the estimated costs if plowing were used on open areas of reference sites 1 and 3. Plowing was not considered feasible on the other site since the land areas there were largely residential, forest, and shoreline.

Cost estimates for site restriction for the three accident sites are given in Table 9. The costs of site restriction were based on the assumption that the land would be condemned, with the least contaminated half decontaminated and then planted with vegetation. The wastes would be spread on the more highly contaminated half, which would then be covered with a biobarrier(2) of rock, earth, and vegetation. Fencing would be erected and a surveillance system established. This stabilization of the contaminant would be used until the technology of transuranic recovery or disposal, or the demand for land, changed to make decontamination of the site both technologically and economically feasible.

COST ANALYSIS

In developing the cost estimates for the study, it was assumed that following an accident, the transuranic contamination would lie on the land surface and be almost totally removed by a single application of the decontamination technique appropriate to that surface area. On open areas, earth removal, plowing, and site restriction were considered mutually exclusive alternatives. As a result, a cost gradient related to contamination level is not apparent in these cost estimates. The cost estimates prepared for WASH-1400(1) do show a cost gradient, but that report deals with radionuclides in different forms and with different characteristics from those of the transuranics considered in the present study.

A comparison of the pertinent costs of decontaminating and reclaiming a square kilometer of cropland by dilution (plowing) or removal of the contaminant is shown in Table 10. This comparison indicates that, where the contamination level and land characteristics permitted substitution of plowing for earth removal, plowing would result in a substantially lower cost. None of the population-related costs likely to be incurred are included in this example.

TABLE 8. Comparative Decontamination Costs ($ 1977) for Areas Where Plowing is a Feasible Alternative

Cost Element	Description		1-m Depth		25-cm Depth	
			1.0 km²	10.0 km²	1.0 km²	10.0 km²
Reference Site One						
$\sum_{n=1}^{n} K_n A_n$	Corn Fields		$ 87,700	$ 856,600	$ 74,200	$ 741,900
	Plowed Farmland		81,800	817,500	45,100	451,300
	Hay and Soybeans		28,000	280,200	24,000	239,900
	Pasture		36,000	196,200	19,900	108,300
	Woodlots	Earth Removal	50,500	168,500	50,500	168,500
	Residential Areas		1,800	855,400	1,800	855,400
	Industrial Areas		44,900	269,100	44,900	269,100
DK_e	Temporary Storage		300	3,900	300	3,900
$\sum_{r=1}^{r} K_r L_r$	Land Reclamation		1,627,900	15,217,700	205,200	1,790,400
$\sum_{u=1}^{u} K_u L_u$	Lawn Resodding		--	1,020,400	--	1,020,400
$X_1 \sum_{r=1}^{r} K_r T$	Agricultural Production Loss		45,600	403,200	22,800	201,600
FK_e	Final Disposal		10,728,000	131,120,000	10,728,000	131,120,000
TC	Total Decontamination-Related Cost		12,700,000	151,200,000	11,200,000	137,000,000
Reference Site Three						
$\sum_{n=1}^{n} K_n A_n$	Pasture Land		189,700	1,896,600	104,700	1,046,900
	Field Crops		66,800	683,100	57,200	584,900
	Orchards	Earth Removal	41,300	413,000	41,300	413,000
	Ditches		17,700	177,000	17,700	177,000
	Residential Areas		6,100	118,300	6,100	118,300
DK_e	Temporary Storage		500	3,600	500	3,600
$\sum_{r=1}^{r} K_r L_r$	Land Reclamation		1,854,000	18,675,600	354,200	3,557,000
$\sum_{u=1}^{u} K_u L_u$	Lawn Resodding		7,700	25,500	7,700	25,500
$X_1 \sum_{r=1}^{r} K_r T$	Agricultural Production Loss		47,500	478,600	23,800	232,800
FK_e	Final Disposal		18,714,400	121,584,000	18,714,400	121,584,000
TC	Total Decontamination-Related Cost		20,900,000	144,100,000	19,300,000	127,700,000

NOTE: Total cost is rounded to the nearest $100,000. Population-related costs are not included since they do not depend on the decontamination method chosen.

TABLE 9. Site Restriction Costs ($ 1977) for Reference Site Areas of 1.0 km^2 and 10.0 km^2

Cost Element	Description	Reference Site One		Reference Site Two		Reference Site Three	
		1.0 km^2	10.0 km^2	1.0 km^2	10.0 km^2	1.0 km^2	10.0 km^2
ETK_tP	Evacuation	$ 6,800	$ 2,463,800	$ 1,021,100	$ 3,690,000	$ 17,600	$ 54,000
MK_tP	Population Monitoring and Decontamination	4,500	1,642,500	680,700	2,460,600	11,700	36,000
S	Survey and Samples	161,500	1,069,200	395,800	1,361,300	164,100	517,700
Q	Surveillance	15,000	90,600	15,000	90,600	15,000	90,600
RK_tP	Population Relocation	52,500	19,162,500	7,941,500	28,707,000	136,500	420,000
ZK_t	Real Estate Value:						
	Agricultural	140,600	1,243,200	63,600	1,172,200	146,500	1,475,600
	Residential	200,000	69,160,000	28,158,000	102,752,000	494,000	1,482,000
	Commercial	75,000	27,375,000	--	--	--	--
YK_t	Stabilization and Restriction	94,298,000	938,731,000	95,015,000	938,908,000	94,191,000	937,082,000
VK_t	Present Value of Surveillance(a)	250,000	1,510,000	250,000	1,510,000	250,000	1,510,000
TC	Total Cost	95,200,000	1,062,400,000	133,500,000	1,080,700,000	95,400,000	942,700,000

(a) 100-year period.

NOTE: Total cost is rounded to the nearest $100,000.

TABLE 10. Cost Comparison for Removal and Dilution Techniques for Transuranic Contamination of 1 km^2 of Cropland ($ 1977)

Activity	Earth Removal (Grader)	Plowing 1-m Depth	Plowing 25-cm Depth
Soil Stabilization	$ 177,000	$ 177,000	$177,000
Decontamination	226,000	34,500	3,500
Temporary Storage	3,500	---	---
Final Disposal	119,200,000(a)	---	---
Reclamation	1,806,000	1,871,000	208,500
Production Loss	48,000	48,000	24,000
Total	$121,460,500(a)	$2,130,500	$413,000

(a) If ultimate disposal of the contaminated were in a commercial repository instead of a Federal repository, the estimated cost for that factor would be $14,700,000, and the total cost for the soil removal treatment as defined in this table would be $16,960,500.(8,9)

In agricultural and nonurban areas in general, the cost of final disposal of the earth removed accounted for approximately 98% of the total estimated cost per km^2, shown in Table 10. In residential areas final disposal accounted for 92% of the total estimated cost. If commercial instead of Federal repositories were used, these numbers would be 85% and 50%, respectively. The effect of final disposal cost on total costs indicates that examination of alternative means of dose reduction (e.g., dilution and/or site restriction) would be warranted in a real accident. If the commercial repositories are assumed, then population evacuation and monitoring costs and production losses become the largest items for the residential and commercial areas.

Cost comparisons of alternative means of complying with the Guidance for contaminated areas are given in Table 11 for the 1 km^2 areas and Table 12 for the 10 km^2 areas. Although comparative costs are presented for plowing, site restriction, and earth removal, it does not necessarily follow that

TABLE 11. Cost Summary for Reference Sites 1.0 km^2 in Area

Cost Categories	Earth Removal	Plowing, 1 m(a)	Plowing, 25 cm(a)	Site Restriction(b)
-Reference Site One-				
Evacuation and Monitoring	$ 11,300	$ 11,300	11,300	$ 11,300
Samples and Surveillance	176,500	176,500	176,500	426,500(c)
Decontamination	451,700	328,700	260,400	--
Temporary and Final Disposal	113,243,300	10,728,300	10,728,300	--
Land Reclamation	1,616,500	1,627,900	205,200	--
Production Losses	53,900	53,900	31,100	--
Real Estate Purchase	--	--	--	415,600
Population Relocation	--	--	--	52,500
Site Stabilization	--	--	--	94,298,000
Total	115,600,000	12,900,000	11,400,000	95,200,000
-Reference Site Two-				
Evacuation and Monitoring	$ 1,701,800	$ --	$ --	$ 1,701,800
Samples and Surveillance	410,800	--	--	660,800(c)
Decontamination	602,000	--	--	--
Temporary and Final Disposal	89,402,600	--	--	--
Land Reclamation	458,200	--	--	--
Production Losses	680,700	--	--	--
Real Estate Purchase	--	--	--	28,221,600
Population Relocation	--	--	--	7,941,500
Site Stabilization	--	--	--	95,015,000
Total	93,300,000	--	--	133,500,000
-Reference Site Three-				
Evacuation and Monitoring	$ 29,300	$ 29,300	$ 29,300	$ 29,300
Samples and Surveillance	179,100	179,100	179,100	429,100(c)
Decontamination	425,000	321,600	227,000	--
Temporary and Final Disposal	118,726,700	18,714,900	18,714,900	--
Land Reclamation	1,779,200	1,861,700	361,900	--
Production Losses	59,200	59,200	35,500	--
Real Estate Purchase	--	--	--	640,500
Population Relocation	--	--	--	136,500
Site Stabilization	--	--	--	94,191,000
Total	121,200,000	21,200,000	19,500,000	95,400,000

(a) Earth removal is assumed to be used in areas not suited to plowing.
(b) Site restriction costs are based on construction of a biobarrier.
(c) Site restriction surveillance is for a 100-yr period.
NOTE: Total cost is rounded to the nearest $100,000.

TABLE 12. Cost Summary for Reference Sites 10.0 km^2 in Area

Cost Categories	Earth Removal	Plowing, 1 m(a)	Plowing, 25 cm(a)	Site Restriction(b)
-Reference Site One-				
Evacuation and Monitoring	$ 4,106,300	$ 4,106,300	$ 4,106,300	$ 4,106,300
Samples and Surveillance	1,159,800	1,159,800	1,159,800	2,669,800(c)
Decontamination	4,636,500	3,443,500	2,834,400	--
Temporary and Final Disposal	1,096,672,200	131,123,900	131,123,900	--
Land Reclamation	17,060,300	16,238,100	2,810,800	--
Production Losses	3,414,500	3,414,500	3,212,900	--
Real Estate Purchase	--	--	--	97,778,200
Population Relocation	--	--	--	19,162,500
Site Stabilization	--	--	--	938,731,000
Total	1,127,000,000	159,500,000	145,200,000	1,062,400,000
-Reference Site Two-				
Evacuation and Monitoring	$ 6,151,500	$ --	$ --	$ 6,151,500
Samples and Surveillance	1,451,900	--	--	2,961,900(c)
Decontamination	5,939,200	--	--	--
Temporary and Final Disposal	1,084,751,900	--	--	--
Land Reclamation	2,337,900	--	--	--
Production Losses	2,460,600	--	--	--
Real Estate Purchase	--	--	--	103,924,200
Population Relocation	--	--	--	28,707,000
Site Stabilization	--	--	--	938,908,000
Total	1,103,100,000	--	--	1,080,700,000
-Reference Site Three-				
Evacuation and Monitoring	$ 90,000	$ 90,000	$ 90,000	$ 90,000
Samples and Surveillance	608,300	608,300	608,300	2,118,300(c)
Decontamination	4,236,000	3,288,000	2,340,100	--
Temporary and Final Disposal	1,189,650,900	121,587,600	121,587,600	--
Land Reclamation	17,866,500	18,701,100	3,582,500	--
Production Losses	514,600	514,600	268,800	--
Real Estate Purchase	--	--	--	2,957,600
Population Relocation	--	--	--	420,000
Site Stabilization	--	--	--	937,082,000
Total	1,213,000,000	144,800,000	128,500,000	942,700,000

(a) Earth removal is assumed to be used in areas not suited to plowing.
(b) Site restriction costs are based on construction of a biobarrier.
(c) Site restriction surveillance is for a 100-yr period.
NOTE: Total cost is rounded to the nearest $100,000.

the least-cost method would be selected for application in a real situation. Responsible officials would make their choice after considering not only cost but also such factors as health risks, economic disruption, and ecological impacts. For instance, plowing would be less costly than earth removal, but equipment for 1-m plowing would probably not be readily available, and where clay or loose rock underlay the topsoil, land reclamation problems caused by plowing might be very costly. Plowing to a depth of 25 cm would be the least costly technique for use on open areas, but it might be less effective in reducing dose rates than would earth removal or 1-m plowing.

Site restriction without removal of the contamination would only buy time, shifting much of the cost into the future. As estimated in this report, the costs of site restriction techniques--excluding costs for population evacuation, monitoring, and relocation; site purchase (necessary to eliminate the economic burden on owners of affected land); and fencing--would range from about $\$415{,}000/km^2$ to $\$9{,}000{,}000/km^2$. The low estimate would be for initial sampling and surveillance, use of a short-term stabilizer, and revegetation. This treatment would be comparable to the minimum treatment estimate of $500/acre ($\$123{,}500/km^2$) noted in the Guidance. The higher estimate would be for use of a biobarrier.

Table 13 presents a comparison of estimated cumulative costs/km^2 for all sites and treatments discussed in this report. Differences in the costs per unit area between the 1 km^2 and 10 km^2 areas are largely accounted for by population evacuation and monitoring factors. In real instances, one would expect greater differences due to scale economy effects. As noted earlier, the use of unit costs in this analysis precluded the demonstration of such effects.

Table 14 shows a comparison of unit costs developed in the DOE analysis and those estimated by EPA. The comparisons shown in the table are somewhat contrived since the definitions of the items and the assumptions used by EPA and DOE are, in many cases, quite different. (See Table 1 and Appendices B, C, and D for details of many of the DOE definitions and assumptions.)

TABLE 13. Comparison of Estimated Cumulative Costs per Unit Area for All Sites and Treatments

Area	Treatment[a]	Total Cost ($ Million 1977)	Cost/km^2 ($ Million 1977)	Cost/acre ($ Thousand 1977)
1.0 km^2:				
Reference Site One	ER	115.6	115.6	468
	SR	95.2	95.2	385
	DP	12.9	12.9	52
	SP	11.4	11.4	46
Reference Site Two	ER	93.3	93.3	378
	SR	133.5	133.5	540
Reference Site Three	ER	121.2	121.2	490
	SR	95.4	95.4	386
	DP	21.2	21.2	86
	SP	19.5	19.5	79
10.0 km^2:				
Reference Site One	ER	1127.0	112.7	456
	SR	1062.4	106.2	430
	DP	159.5	16.0	65
	SP	145.2	14.5	59
Reference Site Two	ER	1103.1	110.3	446
	SR	1080.7	108.1	437
Reference Site Three	ER	1213.0	121.3	491
	SR	942.7	94.3	382
	DP	144.8	14.5	59
	SP	128.5	12.9	52

---

[a] ER = Earth removal to depth of 5 cm; DP = Deep (1-m) plowing; SP = Shallow (25-cm) plowing; SR = Site restriction, including construction of a biobarrier.

TABLE 14. Comparison of DOE and EPA Unit Costs for Area Decontamination and Management

	DOE	EPA(a)			
	Cost Plus Burden(b)	Low Cost	High Cost	Assumed Unit Cost	EPA Definitions and Assumptions
Two Weeks of Water Fixation	$ 73,500/km^2	$ 49,400/km^2	$ 296,000/km^2	$ 172,900/km^2	Short-term stabilization.
Long Acting Stabilizer	103,500/km^2	128,400/km^2	163,000/km^2	148,200/km^2	Long-term stabilization.
Corn Removal	20,000/km^2				No estimate.
Other Crop Removal	4,000/km^2				No estimate.
Earth Removal (Grader)	226,000/km^2	37,000/km^2	405,100/km^2	148,200/km^2	Scraping into mounds.
Earth Removal (Front End Loader)	412,500/km^2				
Earth Removal (Manual Labor)	710,500/km^2				
Field Sod Removal	226,000/km^2	8,600/km^2	185,200/km^2	123,500/km^2	
Lawn Sod Removal	282,000/km^2				No estimate.
Vacuumized Sweeper for Streets	40,000/km^2				No estimate.
Fire Hosing	50,000/km^2				No estimate.
Homes	350/home				No estimate.
Population Monitoring & Decontamination	---				No estimate.
Evacuation, Including Room, Board, Transportation and Personnel(2, p. 12-3)	---				No estimate.
Lawn Resodding	1,275,500/km^2	101,300/km^2	469,300/km^2	259,400/km^2	Seeding, not sod. Probably assumes open areas.
Topsoil Replacement	1,597,500/km^2	352,000/km^2	774,300/km^2	563,200/km^2	Assumes soil needed on 95% of area.
Erosion Control	208,500/km^2	137,000/km^2	209,900/km^2	179,100/km^2	Long-term stabilizer plus mulch.
Fertilizer + Seed (Materials Only)	65,000/km^2	54,300/km^2	175,400/km^2	88,900/km^2	Includes application.
Temporary Storage Sites (Except Land Cost)	3,500/km^2				No estimate.
Plowing					
25 cm	3,500/km^2	4,900/km^2	16,100/km^2	11,100/km^2	"Shallow" plowing.
1 m, Tilled Land	34,500/km^2	7,400/km^2	163,000/km^2	49,400/km^2	"Deep" plowing.
1 m, Pasture, Including Reseeding(1, p. 12-11)	150,000/km^2				
Surveillance (Based on Perimeter Length)	6,000/km	30,000/yr	57,000/yr	No estimate	Guard service, no area basis.
Commercial Areas	897,000/km^2				No estimate.
Disposal (1000 Miles of Transportation, 2" Soil Removal)	119,200,000/km^2	123,500,000/km^2	185,250,000/km^2	164,255,000/km^2	
Biobarrier (Labor and Materials)	17,742,000/km^2				No estimate.
Fence (Based on Perimeter Length)	47,000/km	600/km	3,400/km	2,300/km	Computed equivalent based on EPA cost/10 acres.
Present Value of Future Surveillance	100,000/km^2(c)				No estimate.

(a) Taken from EPA Guidance Summary Report,(11) Table VI-2, "Decontamination Costs." EPA given in \$/acre converted to \$/km^2 for this table. The EPA document includes cost estimates for some treatment measures not used in DOE estimates.

(b) Burden costs include overhead (25%), loss of efficiency due to protective clothing (30%), workmen's compensation and social security (10%), except for land reclamation costs which do not require protective clothing and include only overhead and social security. All unit costs are rounded to the nearest \$500.

(c) Cost estimate does not assume any burden.

Nevertheless, the table is a helpful point of departure for a discussion of the reasons for the differences between the cost estimates of DOE and EPA. The estimates differ by a factor of about 3 or less, except for lawn resodding (where the EPA estimate is for seeding while the DOE estimate is based on application of sod) and fencing (where the basis for the EPA estimate is not specified and DOE assumes use of a high chain-link fence). The differences noted in Table 14 do not account for the more substantial differences between the EPA and the DOE estimates of overall treatment costs per unit of area.

In the Guidance Summary Report, (11, section 2, p.17) it is noted that "A minimum cost of $500 per acre [$123,500/km^2] has been assumed for estimating the costs which may be incurred in bringing all areas above the designated level into compliance." This figure is nearly two orders of magnitude smaller than the minimum DOE estimated costs/km^2 indicated in Table 13. The major differences between the DOE estimated costs/km^2 and the EPA's $500/acre minimum estimate are the treatment assumed and the associated activities considered. The EPA minimum estimate includes only initial radiological surveillance, application of a short-term soil stabilizer, and revegetation with grass, although the EPA presents unit cost estimates for a broad range of other treatment alternatives (11, Table VI-2). The DOE estimates, as discussed in the preceding pages, include as essential actions: evacuation and monitoring of the human population from the affected site, radiological samples and site surveillance, site decontamination, temporary and final disposal of any contaminated soils and vegetation removed from the site, land reclamation, production losses due to interruption of economic activities, and--where decontamination is not feasible--site stabilization, real estate acquisition, and permanent relocation of population.

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APPENDIX A

SITE DESCRIPTIONS

APPENDIX A

SITE DESCRIPTIONS

Since the analysis of impacts is presented specifically for each reference site, the site-specific variables are given here as simply and as explicitly as possible. A modified outline format allows easy identification of the reference sites and quick comparisons of factors across sites.

The site descriptions included in this section served as the basis for the development of site-specific decontamination plans (Appendix C) and impact analyses (Section II and Appendix E). The sites were selected 1) to include the land types deemed important, 2) to occur in different important biomes, and 3) to be well-documented.

Each site description that follows includes all information needed to identify detailed decontamination steps to be used as a basis for analysis of the site. Specifically mentioned are characteristics which affected the selection of alternative decontamination techniques and the rate at which the decontamination effort might be expected to be accomplished. Analyses were conducted for each site on the alternative assumptions that 1-km^2 and 10-km^2 areas were found, after the hypothetical contaminating events, to require remedial treatment.

REFERENCE SITE ONE

Topography: The area is a floodplain. Ravines are the principal feature to the west and east of the floodplain. The elevation is approximately 1000 ft (300 m) above sea level. A major river flows next to the accident site.

Climate: Rapidly changing weather; the area is located midway between two distinctive climatic zones (humid-east and dry-west). The average temperature is 53°F (12°C).

Rainfall: Average annual rainfall: 30 in. (76 cm).

Vegetation: Native grasses and shrubs, with ash, elm, and cottonwood trees along bluffs.

Land Use: Within a 10-mile (16-km) radius of the accident site, 70% of the land area was assumed to be in farms. A breakdown of the area into land types follows:

Corn Fields - 37%
Hay and Soybeans - 14%
Idle Farmland - 25%
Pasture Land - 7%
Forest - 3%
Population Areas - 14%

Population Distribution in Cleanup Areas:

Area (km^2)	Population
1.0	15
10.0	5475

Description of Contaminated Area:

- Depth Profile - All plutonium was assumed to be located on or near the surface, since a fresh deposition was being considered.
- Isotopic Mixture - (wt%)

  ^{238}Pu - 1.4%
  ^{239}Pu - 58.0%
  ^{240}Pu - 24.0%
  ^{241}Pu - 9.0%
  ^{242}Pu - 4.9%
  ^{241}Am - 2.4%

- Areas to be Decontaminated -

Land Type	Area (km^2)	
	1.0	10.0
Corn Fields	0.37	3.70
Idle Farmland	0.25	2.50
Hay and Soybeans	0.13	1.30
Pasture Land	0.11	0.60
Residential Area	5 Homes	1.40
Commercial Area	0.05	0.20
Forest	0.09	0.30

REFERENCE SITE TWO

Topography: Moderate variation in elevation, with ground elevation 0-40 ft (0-12 m) above sea level.

Climate: The mean daily maximum and minimum air temperatures during the warmest month are 83°F and 64°F (51°C and 18°C), respectively. Daily minimum temperatures for the coldest months average about 22°F (-5.5°C).

Rainfall and Humidity: Average annual rainfall: 45 in. (114 cm). Average relative humidity: 75%.

Soils: Glacial Soils - sand and gravel (till and outwash).

Ground Water: There is no danger that surface drainage from the accident site could affect public reservoirs, because of the low permeability of soils in the area and a ground water gradient sloping from the reservoir to the site.

Vegetation and Wildlife: The area comprises mainly secondary-growth hardwood forests. Hardwoods include beech, sugar maple, and birch, with hemlock also abundant. Wildlife includes woodchucks, skunks, racoon, grey squirrels, and cottontail rabbits. A wide variety of upland birds and sea birds is present in the vicinity of the accident site.

Population Distribution in Cleanup Areas:

Area (km^2)	Population
1.0	2269
10.0	8202

Description of Contaminated Area:

- Depth Profile - Contamination was assumed to be located on or near the surface, since a fresh deposition was being considered.
- Isotopic Mixture - (wt%)

  ^{238}Pu - 1.4%

  ^{239}Pu - 58.0%

  ^{240}Pu - 24.0%

  ^{241}Pu - 9.0%

  ^{242}Pu - 4.9%

  ^{241}Am - 2.4%

- Areas to be Decontaminated -

Land Type	Area (km^2)	
	1.0	10.0
Forest	0.21	3.96
Shoreline	0.22	3.96
Population	0.57	2.08

REFERENCE SITE THREE

Location and Topography: Located between two mountain ranges. The terrain around the accident site is flat-to-light-rolling at an elevation of 130-280 ft (40-85 m) above sea level. Rainy winters are typical, with fair summer, spring, and fall seasons.

Climate: Temperatures are greater than 90°F (32°C) on 80 days/yr, and less than 32°F (0°C) on 32 days/yr.

Rainfall and Humidity: Average annual precipitation: 16 in. (41 cm). Humidity is greatest in the winter (88% average), compared with 48% in the summer.

Soils: Hard-to-very-hard-silts, and silty clays with dense-to-very-dense sands and gravels.

Surface and Ground Water: The area is bounded by well-defined drainage courses and natural gullies that intercept surface runoff from the higher surrounding terrain. Unconfined or semiconfined ground-water conditions occur in this area: ground-water levels are about 157 ft (48 m) below the ground surface.

Vegetation and Wildlife: Vegetation is predominately bunchgrasses and various other grasses. Mammals in the area include ground squirrels, jackrabbits, coyotes, badger and skunk.

Land Use: In a 5-mile (8-km) radius from the accident site, land is exclusively agricultural. Grazing land dominates, with some field crops and orchards. No dairy cattle are located within the 5-mile radius.

Population Distribution in Cleanup Areas:

Area (km^2)	Population
1.0	39
10.0	120

Description of Contaminated Area:

- Depth Profile - All plutonium was assumed to be located on or near the surface, since a fresh deposition was being considered.
- Isotopic Mixture - (wt%)

^{238}Pu - 1.4%

^{239}Pu - 58.0%

^{240}Pu - 24.0%

^{241}Pu - 9.0%

^{242}Pu - 4.9%

^{241}Am- 2.4%

- Areas to be Decontaminated -

Land Type	Area (km^2)	
	1.0	10.0
Pasture Land	0.58	5.80
Field Crops	0.31	3.17
Orchards	0.07	0.70
Irrigation Ditches	0.03	0.30
Residential Area	0.01	0.03

APPENDIX B

SAMPLING

APPENDIX B

SAMPLING

The sampling scheme presented in this section was developed solely to provide a basis for estimating costs in the analysis of the three hypothetically contaminated reference sites discussed in this report. While the scheme was designed to be consistent with the requirements of the Guidance, it should not be considered in any way a guide for actual sampling programs for real incidents. Sampling programs for use in such cases would have to be designed for the specific circumstances of those incidents, including such variables as site location, land types, involved meteorological conditions, and precipitation. Following the Guidance, it was concluded that the sampling scheme would need to:

- Define those land areas in which the contamination exceeded the soil screening level (0.2 μ Ci/m^2).
- Provide a basis for determining those areas in which dose rates to human occupants would be expected to exceed 1 mrad/yr to the pulmonary lung or 3 mrad/yr to the bone.
- Provide a basis for choices among possible remedial treatment methods.
- Assess the extent of residual contamination following remedial treatment of the affected areas.

Three factors were considered in costing: 1) labor needed to collect the samples, 2) laboratory analysis of the samples, and 3) power supply for the air samplers. Equipment needed for sampling (e.g., portable alpha meters, FIDLERs, Ge(Li) vans, and air samplers) was assumed to be available at nominal or no cost. A labor cost of $2.50/sample or survey reading was used, based on the assumption that it would take two monitors 10 min to obtain one sample. This cost may seem high, but it allowed for time to move to the next sampling location. Analysis of all samples (soil, air, vegetation, foodstuff, urine, and animal feces) was assumed to cost $100/sample. These analyses would give the isotopic breakdown necessary for dose calculations. Several particle-size fractionation studies of air samples were also assumed to be necessary for dose calculations. Power lines were assumed installed for the operation of air samplers in the affected areas at costs of \$3/ft (\$10/m) for lines installed above ground and \$10/ft (\$33/m) for underground installation.

For most aspects of the sampling program, it was assumed that the number of samples required, and therefore the cost, was sensitive to the size of the affected areas but not to other differences in the areas. While this is contrary to expectations for real incidents, as noted above, it was considered an appropriate simplification for the kind of analysis reported here. Two exceptions to this simplification were made. Numbers of samples, and costs, for monitoring of the human population and for analyzing possible contamination of foodstuffs were estimated specifically for each site and for the ultimate assumptions that 1 km^2 and 10 km^2 required remedial treatment. A summary of the assumed sampling requirements is presented in Table B.1.

The proposed EPA Guidance states (page 14 of Annex V) that "acceptance criteria which allow a maximum chance of error of 5-10% are generally considered appropriate." It is assumed that this statement refers to the two types of decision errors that could be made: first, deciding that remedial action is required when that is actually not the case; and second, deciding not to take remedial action when such action should be taken according to the guideline. By specifying acceptable probabilities for these two errors, it is possible in a real situation to estimate the number of samples that should be taken to detect a contamination level greater than the Guidance value. The approximate numbers of samples given in Table B.1, however, were not derived on the basis of any specification of the two decision errors because the Guidance gives no indication of the statistical test criteria for determining whether or not Guidance limits have been exceeded. Different test criteria would result in different requirements for numbers of samples.

TABLE B.1. Approximate Sampling Requirements for Delineating Areas Needing Remedial Treatment and Assessing Treatment Adequacy[a]

Definition of Areas Exceeding Soil Screening Level[b]	Hypothetical Cleanup Area	
	1 km^2 (Number of Samples)	10 km^2 (Number of Samples)
1. Instrument Ground Surveys along Radii		
• FIDLER	800	800
• ALPHA	1000	1000
• Ge (Li)	100	100
2. Soil Samples along Radii	150	150
3. Profiles for Depth Characterization	120[c]	120[c]
4. Soil and Instrument within Sampling Units		
• Ge (Li)	400	400
• Soil	100	100
Dose Estimation		
5. Soil and Instrument Surveys		
• Ge (Li)	50	100
• Soil	50	100
6. Air Samples[d]	500	3200
7. Vegetation	75	150
8. Foodstuffs		
• Site 1	20	100
• Site 2	20	250
• Site 3	20	100
9. Population (Human) Monitoring		
• Site 1	50	16,500
• Site 2	6800	24,500
• Site 3	120	400
10. Water and Sediments	35	70
11. Wildlife and Domestic Animals	25	25
Post Cleanup Sampling		
12. Soil and Instrument		
• Ge (Li)	150	300
• Soil	150	300
13. Air Samples	100	200
14. Vegetation	50	100
15. Foodstuffs		
• Site 1	10	50
• Site 2	10	125
• Site 3	10	50
16. Water and Sediments	50	100
17. Wildlife and Domestic Animals	25	50
18. Population (Human) Monitoring		
• Site 1	20	5500
• Site 2	2300	8200
• Site 3	40	120

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[a] The numbers of samples given here were used as a basis for cost estimating in this analysis; they are not suitable for use as guides for actual sampling programs. Any real contamination incident would require development of a sampling plan specific to the circumstances involved.

[b] The number of samples and survey measurements for the 1 km^2 and 10 km^2 assumptions are identical in this table since the effort needed to define the areas exceeding the soil screening level may be independent of the size of these areas.

[c] Thirty locations; 4 depths per location.

[d] Includes particle size analyses on some samples.

DEFINITION OF AREA CONTAMINATED BEYOND THE SOIL SCREENING LEVEL

Meteorological conditions at the time of any real contaminating incident would be considered in planning the initial ground surveys. For purposes of this analysis, it was assumed that the ground was surveyed on radials running out from the accident site at 15° intervals (Figure B.1) as necessary to define the boundaries of the area contaminated beyond 0.2μ Ci/m^2. One Ge(Li) scan was assumed for each 10 portable instrument readings, the total numbers of each test approximating those shown in Table B.1.

In the assumed sampling program, FIDLER and Ge(Li) detector readings were taken in the field as a check on the validity of alpha readings since the FIDLER and Ge(Li) techniques are sensitive to the 60-keV x-rays from ^{241}Am, rather than the plutonium alphas. Soil particle-size fraction studies were assumed on several soil samples to estimate the distribution of contamination in the various soil-size fractions. This information would be necessary for dose calculations.

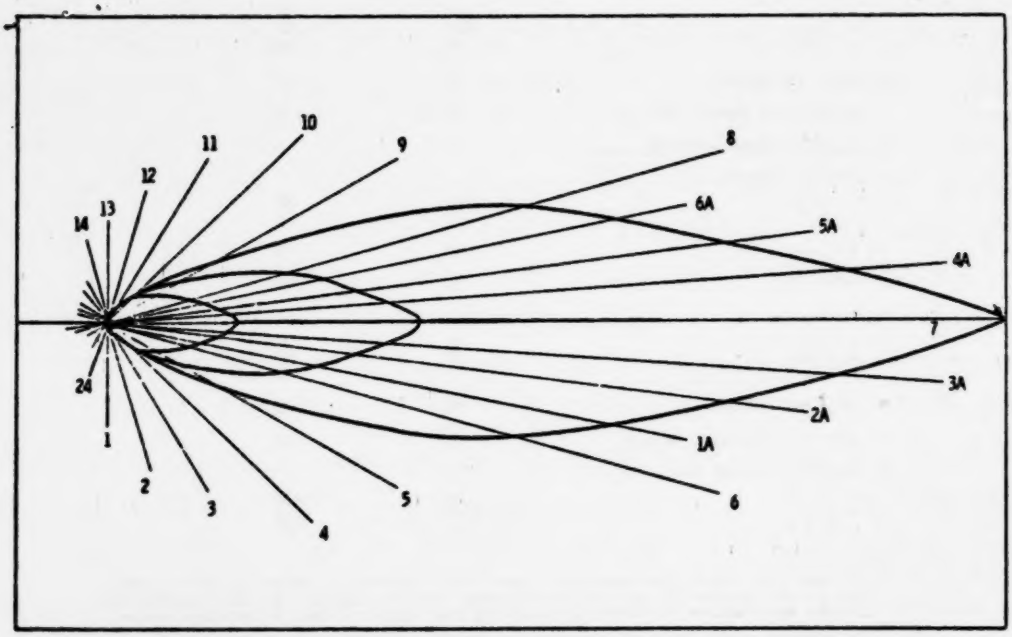

FIGURE B.1. Pattern of Radials for Sampling for a Hypothetical Contaminating Event

Soil profiles were assumed taken at various distances from the accident site and for various land types encountered. The depths to which such profiles would be required in a real incident would depend upon the length of time between the accident and the taking of samples and upon the nature of any disturbance which might have occurred during this period.

The final assumed step in determining the 0.2μ Ci/m^2 boundary involved dividing the land area into sampling units at the approximate boundary. Within these units additional soil and Ge(Li) readings were assumed to be taken. Statistical analysis of these data was assumed to involve such parameters as the arithmetic mean, median, proportion of observations above 0.2μ Ci/m^2, largest concentration obtained, and spatial orientation of the samples.

DOSE ESTIMATION

The next steps in the assumed sampling were the division of the area containing levels greater than 0.2μ Ci/m^2 into activity strata and the collection within these strata of samples of water, sediment, foodstuffs, vegetation, air, small mammals, and additional soil. The number of samples and portable survey readings assumed needed in this phase are presented in Table B.1.

Since inhalation may be the primary pathway for the introduction of plutonium into the body, air monitoring was assumed necessary, especially during decontamination procedures. Several portable air samplers were assumed to be placed upwind (for controls) and downwind from the accident site to help locate any immediate resuspension problems that would need to be considered before survey teams moved in. Particle-size analysis was included to assist in the determination of dose to the lung from respirable soil particles.

It was assumed that following initial characterization, air samplers were placed every 500 ft (152 m) along the perimeter of the 0.2μ Ci/m^2 boundary. Filters were assumed to be changed every 2 wk for up to 1 yr.

The samplers would provide data on the air concentrations of contaminants leaving the area due to the resuspension from ground contamination in the affected area and decontamination operations.

Additional air samplers were positioned within the perimeter during cleanup for the determination of possible occupational risks. Approximately 25 samplers/km^2 were assumed necessary for the 10 km^2 areas in this analysis; 10 samplers/hectare were assumed needed for the 1 km^2 areas. Additional air samplers were also considered to be used in the vicinity of temporary contaminated soil storage mounds.

The following types of samples were assumed collected to help to estimate the dose to man from the ingestion pathway: 1) crops such as wheat, corn, potatoes, tomatoes, etc; 2) water for humans and farm animals; 3) milk, milk products; 4) hair and feces of farm animals and pets; and 5) liver and muscle of cattle, chickens, and other edible farm animals. About 20 samples per farm within the 0.2μ Ci/m^2 boundary were assumed to have been collected. In Table B.1, the number of samples shown under "foodstuffs" is specific to each site and assumes 20 samples per farm; the numbers of farms in the affected areas were estimated by dividing the size of the areas by the average-size farm for the respective regions of the country.

It was assumed that the population within the areas designated for remedial treatment would undergo a personnel survey. Table B.1 shows for each reference site the estimated number of samples requiring analysis, based on the population within the affected area. Follow-up sampling was considered necessary for persons who showed positive results.

Sediments of ponds and rivers in the contaminated areas would be expected to accumulate radionuclides. Accordingly, water and sediment samplers were assumed to be collected, as indicated in Table B.1.

POST CLEANUP SAMPLING

Post cleanup monitoring was assumed to be handled by dividing the decontaminated area into units and taking Ge(Li) scans and soil samples within each unit. Included were several soil profiles needed to determine whether soil had been removed to an adequate depth.

Post cleanup monitoring was also assumed to include samples of air, vegetation, foodstuffs, water, sediment, and animals. Sampling of vegetation was considered to be continued for several years after cleanup to ascertain that plants were not taking up any transuranic materials that might have escaped the decontamination processes. As shown in Table B.1, post cleanup monitoring of the human population within the affected areas was also assumed.

APPENDIX C

REFERENCE DECONTAMINATION PROCEDURES

APPENDIX C

REFERENCE DECONTAMINATION PROCEDURES

The EPA Guidance specifies no procedures for use in stabilizing or decontaminating areas impacted by releases of transuranics. A variety of ways could be proposed to bring contaminated areas into conformance with the Guidance. As a basis for assessing in this analysis the costs and other impacts of compliance with the Guidance sets of procedures were selected which were judged to be realistic, workable approaches to the removal or stabilization of contaminated soils following an accidental release of transuranics. It is unlikely that the selection of alternative procedures to achieve the same ends would have produced large differences in costs or other impacts. However, the procedures described here were assumed for the purposes of illustratory analysis only. The labor requirements and timing assumptions for these procedures, used as a basis for cost estimates, are summarized in Table C.1.

GENERAL APPROACH

Area Restriction, Stabilization, and Evacuation

A series of steps was assumed, solely as a basis for analysis, to be taken following each hypothetical contaminating event:

- The area of suspected contamination was defined.
- Traffic into and out of this area was restricted.
- Individuals in the area were alerted to take appropriate precautions to prevent personal exposure.
- Monitoring teams, equipped with portable equipment, were dispatched to define the area which would probably require remedial treatment.
- People in the probable treatment area were evacuated, examined for radiological contaminants, and housed in temporary evacuation centers

TABLE C.1 Man-Hour Estimates and Removal Deadlines for Decontamination

Land Area	Man-hr/km^2	Cleanup Deadline
1. Cropland (cornfield)		
- Corn Removal	600	1 month
- Soil Removal	2,200	1 year
- Total	2,800	
2. Grazing Land	3,200	1 year
3. Pavement	500	1 month
4. Forest	25,800	1 year
5. Ditches	8,600	1 year
6. Roof Areas		
- Sloped	1,300	1 month
- Flat	6,500	1 month
7. Lawns	11,600	1 month
8. Homes	37,500	1 month
9. Population Area	16,200	1 month
10. Orchards	8,600	1 year
11. Shoreline	15,600	1 year

(e.g., nearby schools or community centers). They were maintained in these centers until survey teams concluded that it was safe for them to return to the area or until more permanent housing was arranged.

- Areas identified as contaminated were treated where appropriate with water spray and later with a longer-acting stabilizer to control the spread of the transuranic materials.

Removal of Contaminated Soils

Where removal of soils was assumed to be a part of the remedial treatment procedure, the following steps were included as a cost basis:

- Soil was scraped to a depth of 5 cm.
- Soil was hauled by dump truck to temporary storage sites (about 1 site for each 2-km^2 contaminated section).
- Soil was bulldozed into temporary mounds for storage, and the mounds were treated with soil stabilizers to prevent resuspension or erosion.
- Within about 1 yr, the soil in the mounds was packaged in 55-gal (208-ℓ) drums and shipped in unshielded vans an average of 1000 miles (1600 km) for ultimate disposal in Federal disposal sites.

These steps were based upon the expectation that the transuranic materials would be concentrated in the top few cm of soil in recently contaminated areas. Fresh depositions would migrate only to a limited depth, according to research on the subject. Jakubick,(1) for instance, predicted a migration rate of only 0.8 cm/yr in soils studied in Germany. Specific cost bases were taken from BNWL-2210,(2) the Tri-State Motor Transit Company,(3) and GESMO.(4)

Plowing of Contaminated Soils

Plowing is a method by which contamination can essentially be buried in place, eliminating the need for costly final burial. Plowing was considered here as an alternative decontamination method for cropland and grazing land.

Plowing to depths of 10 in. and 3 ft (25 cm and 0.91 m) was considered here. Ten-inch plowing was assumed to be done with a 100-hp farm tractor and a standard 7-bottom farm plow. One pass with the plow at a rate of approximately 125,000 m^2/day(a) was predicted to yield a residual fraction of 20%.(b)(5) Assuming one worker per plow, an effort of approximately 8 man-hr/km^2 was estimated to be required.

Deep plowing to 3 ft (~1 m) can bury approximately 95% of the surface contamination deeper than 2·3 ft (0.7 m),(6) which would allow uptake of contamination from only deep-rooted plants. Deep plowing was assumed to be done by two large crawler tractors pulling a moldboard plow, capable of 36-in.-deep furrows.(6,7) A crew of four was considered to be necessary: two tractor drivers, one person at the controls of the plow, and one laborer. About 1 acre (4000 m^2) was estimated to be plowed per hour(7) with an effort of approximately 4 man-hr per acre or 1000 man-hr/km^2.

Post-Decontamination Survey

Final release surveys were considered to be necessary for all decontaminated areas. Steps included resampling, primarily by soil and air monitoring with some portable instrument surveys. Vegetation and foodstuff sampling was considered to be necessary to assure that uptake by plants did not present a risk to the public. Estimates of the number of samples needed for the final release survey are presented in Appendix B.

APPROACHES SPECIFIC TO LAND TYPES

The appropriateness of various decontamination methods would vary with the types of land or land uses affected. Descriptions of methods assumed for various land types and uses in this analysis are presented below in an outline format for easy reference. These descriptions include rate factors needed to make consistent cost estimates for the decontamination methods assessed in this report.

(a) P. Tvergyak, 1978, Extension Economist, Coulee Dam, WA; private communication.

(b) Approximately 20% of the original surface deposition would remain within the top 1 cm and be available for resuspension.

For those methods that involve soil removal, estimates of man-hr requirements are included. Manpower needs for transport of soil to a temporary storage site are described in Appendix D. For final burial, manpower needs were taken from BNWL-2210.(2) Labor requirements for monitoring are presented in Appendix B. Supervisory personnel are accounted for in the discussion of the 25% burden of the unit cost (text Section II).

DECONTAMINATION OUTLINE

I. Cropland

A. Stabilization

A road-type sprayer was assumed used to apply the initial water-spray stabilizer. After the crop was cut and removed, the soil was expected to be covered with a long-acting stabilizer. A 9000-gal-capacity (34,000-ℓ) tanker truck with spray bars and a five-man crew was estimated to be able to apply the stabilizer at a rate of ∿40,000 m^2/day[a] (10 acres/day). The long-acting stabilizer would limit resuspension for 1 to 5 yr,(8) depending on climatic conditions; this would be adequate since decontamination operations were assumed to be completed in a maximum of 1 yr.

B. Characterization

In addition to preliminary monitoring to determine the affected area, soil core samples were assumed to be taken to indicate the depth of soil to be removed. Air monitoring stations were considered to be established on fringe areas to locate any resuspension problems, particularly during the cleanup phase.

C. Crop Removal

The hypothetical contaminating events for this study were assumed to occur in late summer, thus requiring crop removal. The schedule was to have the crop cut and removed within 1 month and the contaminated soil removed within 1 yr following the accident.

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[a] G. M. Holter, 1977, Atlantic Richfield Hanford Company, Richland, WA; private communication.

The crop was assumed to be cut and removed in one operation, using a harvesting-chopping machine. With a three-man crew, ~30 tons (27 tonne) of cropland cover was estimated to be removed per hr. This rate depended upon a mix of crops being cut since, for example, corn could be removed at a rate of 1-1.5 acres/hr (4000-6000 m^2/hr) while hay could be removed at approximately five times that rate. The freshly cut crop was considered to be hauled to a temporary storage site where it was placed in 55-gal (208-ℓ) drums and stored until shipped for permanent burial. An effort of ~600 man-hr/km^2 was estimated to be required for crop removal.

D. Soil Removal

Where necessary, a large road grader (12-in. or 30-cm blade) was assumed to be used to remove the soil down to an appropriate depth. With a three-man crew, the grader could remove soil at a rate of 4.0 equip-min/10^3 ft^2,(5) which is equivalent to an effort of 2200 man-hr/km^2. A front-end loader (5-yd^3 or 4-m^3 capacity) was considered to be used to clean up the windrows left by the grader.

E. Plowing

Where plowing is considered in this analysis, it is assumed that it was accomplished as described under "General Approach," above.

II. Grazing Land

A. Stabilization

The initial water-spray stabilizer was assumed to be applied within 24 hr of the accident, using tanker trucks with spray bars. Water was considered to be applied on alternate days until the long-acting stabilizer was distributed. One-tenth inch (0.25 cm) of water was estimated to be applied at a time. The soil stabilizer was assumed to be applied to affected areas within 1 month.

B. Characterization

Refer to IV-B. In addition, monitoring of cattle (feces and tissue analyses, plus milk analysis for dairy cows) was assumed necessary.

C. Removal

A self-propelled sod machine (20-in. or 51-cm blade) was expected to be used on the grazing land. When removing soil to a depth of 2 in. (5 cm), approximately 10,000 ft^2/hr[a] could be removed. With a three-man crew, ∿3200 $man\text{-}hr/km^2$ would be necessary to complete removal. In areas not accessible to the sod machine, either a front-end loader or manual methods of removal were assumed used. Deadline for removal was set at 1 yr.

III. Forest Land

A. Stabilization

It was assumed that access to the forest was controlled for several months after the accident to allow rainfall to wash contamination into the forest mat.

B. Characterization

Soil and vegetation samples were assumed to be taken periodically during the isolation phase to determine whether contamination was being washed into the forest mat. Air monitoring stations were also posited on the periphery of the forest to identify any resuspension problems.

C. Removal

It was assumed that the forest mat was removed where it was contaminated, leaving most of the trees standing. Half of the mat was considered to be removed by a small front-end loader (1.5 yd^3 or 1.2 m^3 capacity) and half by manual methods. A front-end loader with a two-man crew would require an effort of 8600 $man\text{-}hr/km^2$,(5) while manual shoveling with a four-man crew would require

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[a] D. Jenks, 1977, Redeturf, Inc., Aurora, Oregon; private communication.

43,000 man-hr/km^2.(5) Overall, an effort of 25,800 man-hr/km^2 was estimated to be required. Deadline for cleanup was 1 yr following the accident.

IV. Populated Area

A. Stabilization

In populated areas, it was anticipated that the initial water-spray stabilizer was applied within 24 hr of the accident. Application was by tanker trucks with spray bars, and occurred on alternate days until a long-acting stabilizer was spread. A smaller capacity tanker (2000 gal or 7600 ℓ with one spray nozzle) was assumed to be used to apply the stabilizer to more confined areas of the population center. Initial water-spray and long-acting stabilizers were assumed not to be applied to pavement or roof areas.

B. Characterization

Every home in contaminated areas was assumed to require an interior and exterior survey. The exterior survey involved a check of the roof and chimney area and spot checks of the walls. Interior surveys included a survey of entrances, filtering systems, and easily accessible surfaces (tables, floors, etc.).

If no contamination was found, a complete survey was estimated to require an average effort of 4 man-hr(a) per three-bedroom home. If contamination was found during the survey, it was expected that monitors would need to do a more complete survey requiring approximately 8 man-hr.(a)

C. Removal

1. Pavement

Rough-textured concrete or asphalt roads were assumed to be cleaned up using a vacuumized mechanical sweeping machine traveling at a speed of 4 1/2 mph (7.2 km/hr). Two passes were estimated to be required to get a residual fraction of less than 10%. A work rate of 2.8 equip-min/10^3 ft^2(5) and a one-man crew would yield approximately 500 man-hr/km^2. Removal deadline was set at 1 month, except for evacuation routes that required immediate cleanup.

(a) J. R. Berry, 1977, Pacific Northwest Laboratory, Richland, WA; private communication.

2. Roofs

Firehosing (3/16- x 9/16-in. or 0.48- x 1.4-cm orifice; 120 psi or 8.4 kg/cm^2; 0.12 gal/ft^2 or 4.9 ℓ/m^2)(5) with three persons per nozzle was the assumed method for removing particles contaminated with transuranics. Firehosing of sloped roofs would require 2.4 nozzle-min/10^3 ft^2(5) or 26 nozzle-min/10^3 m^2,(5) or an effort of 1300 man-hr/km^2. Firehosing of flat tar and gravel roofs would require 12 nozzle-min/10^3 ft^2(5) or an effort of 6500 man-hr/km^2. For this study, roof areas were assumed to include 50% sloped roofs and 50% flat tar and gravel roofs; therefore, an effort of 3900 man-hr/km^2 was estimated.

Roofs were assumed to be decontaminated prior to lawn and home exterior cleanup so that contamination displaced from the roof would be removed in later decontamination phases. Some roof runoff might run into storm sewers and from there go either to a sewage treatment plant or a nearby stream or river. For this reason, sludge was assumed to be monitored at sewage treatment plants and packed into 55-gal (208-ℓ) drums for burial if determined to be a risk. Runoff into streams and rivers was considered to be checked by monitoring stations along these waterways. Removal deadline was 1 month.

3. Lawns

Lawns were assumed decontaminated using sod machines; areas not accessible to the self-propelled machine used for the grazing land (refer to II-C) required use of a smaller machine with a 12-in. (0.3-m) blade and a two-man crew. The average effort required for lawn removal was estimated to be 11,600 man-hr/km^2.(9) Removal deadline was 1 month.

4. Home Decontamination

In a 1-km^2 area, homes were considered to take up 23% of the land area (2.5×10^6 ft^2 or 2.3×10^5 m^2). An average home was assumed to occupy $\sim 2.00 \times 10^3$ ft^2 or 190 m^2; therefore, about 1250 homes would occupy 1 km^2. At a cleanup rate of 30 man-hr/home,[a] an effort of 37,500 man-hr/km^2 was estimated to be required for home decontamination. Each decontamination crew consisted of four persons. Removal deadline was set at 1 month.

D. Overall Cleanup Rate

The composition of a populated area was assumed to be the following, based on assumptions in WASH-1400:(10)

1) Lawn, fields - 57%
2) Pavement - 20%
3) Roof - 23%
4) Home and other buildings - 23%

To obtain an estimate of overall effort for the decontamination of a populated area, the above percentages were multiplied by their corresponding man-hr/km^2 values and summed, yielding an assumed effort of 16,200 man-hr/km^2.

V. Shoreline

A. Stabilization

It was assumed that an initial water-spray stabilizer was applied within 24 hr of the accident, using tanker trucks with spray bars wherever possible. Water was considered to be applied on alternate days until the long-acting stabilizer was distributed. The stabilizer was assumed to be spread directly on the shoreline, and all affected areas were considered to be treated within 1 month.

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[a] J. R. Berry, 1977, Pacific Northwest Laboratory, Richland, WA; private communication.

B. Characterization

In addition to preliminary monitoring to determine the extent of the affected area (the area above the guideline limit), soil core samples were assumed to be taken to indicate the depth of soil to be removed where percolation or soil movement was suspected. Air monitoring stations located on fringe areas were posited to identify possible resuspension problems particularly during the cleanup phase.

C. Removal

Since the composition (clay, soils, sand, and gravel) and accessibility of a shoreline are highly variable, several methods were considered to be used in cleanup. The following distribution of methods was assumed for this analysis:

1) Road grader (see I-C) - 25% of shoreline
2) Manual (see III-C) - 25% of shoreline
3) Small front-end loader (see III-C) - 50% of shoreline.

To obtain an estimate of overall effort, the above percentages were multiplied by their corresponding man-hr/km^2 values and summed, yielding an estimated 15,600 man-hr/km^2. The removal deadline for shoreline contamination was set at 1 yr.

VI. Ditches

A. Stabilization

It was expected that where water was flowing in a ditch, the source was diverted, if possible; stabilization then proceeded as in II-A.

B. Characterization

In addition to preliminary monitoring to determine the affected area (the area above the guideline limit), soil core samples were assumed to be taken to indicate the depth of soil and sediments to be removed. Air monitoring stations were considered to be established on fringe areas to identify any resuspension problems, particularly during the cleanup phase.

C. Removal

A small front-end loader (refer to III-C) was considered to be satisfactory for removal of material from broad areas; however, a backhoe was assumed necessary to reach confined areas. Deadline for removal was 1 yr.

VII. Orchards

A. Stabilization

Trees were assumed to be sprayed in an effort to wash the contamination into the orchard mat. An earthen dam was considered to be built around the orchard where needed to contain runoff from the spraying.

B. Characterization

It was assumed that, in addition to preliminary monitoring to determine the extent of the affected area, soil core samples were taken to indicate the depth of soil to be removed. Air monitoring stations were considered established on fringe areas to identify any resuspension problems, particularly during the cleanup phase.

C. Removal

It was assumed that cleanup of the orchard mat was done entirely by a small front-end loader (refer to III-C) since larger areas would be available for maneuvering equipment in an orchard than in a forest area. Deadline for removal was 1 yr.

VIII. Rivers

It was expected that no attempt would be made to clean up river or stream bottoms. Patrol of the river was assumed to be necessary to prevent water traffic in and out of affected reaches until the extent of any possible risk was established. Environmental sampling locations to test water and sediments, including shorelines, were expected to be established at locations such as dams and river bends downstream from the affected area, where particulate settling could occur. Sediments in settling basins at water treatment facilities near the affected area were also considered to be analyzed periodically. This type of monitoring might be continued less frequently after the first year.

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APPENDIX D

UNIT COST DETERMINATIONS

APPENDIX A

UNIT COST DETERMINATIONS

BASIC COMPONENTS

The basic components upon which unit costs were based are identified in Table D.1.

TABLE D.1. Basic Components of Unit Cost

1. Equipment
2. Work Crews
3. Support Personnel
4. Supplies
5. Equipment decontamination
6. Transportation to a temporary storage site

Equipment for decontamination operations was assumed to be leased on a per month basis except for the vacuumized sweeper, which was assumed to be purchased because decontaminating it would be difficult following cleanup operations. For several unit cost determinations (e.g., manual earth removal and home decontamination), no equipment cost was included in the initial decontamination phase because this cost added insignificantly to the total unit cost. Equipment costs for firehosing were not considered because the equipment was assumed to be available from local fire companies. Table D.2 describes the equipment used in cleanup and lists average costs for daily and monthly leasing.

Work crews were assumed to include equipment operators and several laborers. Standard union wages were considered for these workers - $10.85/hr for equipment operators and $5.41/hr for general laborers. Support personnel would include foremen and radiation monitors. The assumption was made that one foreman would be required for every 50 persons involved in the decontamination operations, and one radiation monitor for every five persons. The wage rate was considered to be $10.20/hr for foremen and $7.56/hr for the monitors.

TABLE D.2. Equipment Descriptions and Leasing Rates Without Crews[a]

Type of Equipment	Description	Leasing Rate Monthly	Leasing Rate Daily
1. Water-Tanker Truck	9,000-gal capacity	$2,300	$ 77
2. Crop Harvestor-Chopper	2-row	1,000	33
3. Farm Tractor	100 hp	2,200	73
4. Front-End Loader	270 hp, 5-yd^3 capacity	5,100	170
5. Front-End Loader	100 hp, 1-1/2-yd^3 capacity	1,700	56
6. Grader	12-ft blade	2,500	84
7. Sod Machine	200 hp, 20-in. blade	3,100	103
8. Sod Machine	10 hp, 12-in. blade	1,200	40
9. Bulldozer	320 hp	7,040	235
10. Dump Truck	200 hp	1,400	46
11. Plow	7-bottom	450	15
12. Vacuumized Sweeper	17 hp	7,500[b]	

(a) Costs were developed from a cost estimating guide(1) and quotes by suppliers, in an effort to develop average costs for the U.S.

(b) Assumed purchased.

Supply costs included in unit costs were for the long-acting soil stabilizer, asphaltic emulsion, and fuels. Costs for the long-acting stabilizer and asphaltic emulsion were obtained from Bruns, et al.(2) Ninety percent of the estimated unit costs for the long-acting soil stabilizer ($62,500/km^2) were materials costs. The unit cost for water fixation has entirely labor cost, due to the assumed need for repetitive application (every other day for 2 wk). Fuel costs used were $0.428/gal ($0.110/ℓ) for diesel fuel and $0.60/gal ($0.16/ℓ) for gasoline.

Factors considered in the decontamination of equipment included costs for labor and radiation monitors. The time required to clean one piece of equipment was assumed to be 1 man-day each for labor and radiation monitors.

Transportation to a temporary storage (burial) site was assumed to involve costs for equipment (a dump truck) and truck drivers. Estimated costs at the storage site included equipment (bulldozer) and equipment operator costs.

The unit costs for a temporary storage site, surveillance, population monitoring, and land reclamation presented in Table II.2 of Section II do not follow the basic outline presented in Table D.1. The unit cost for the temporary storage site included costs for the application of soil stabilizer and for a guard. One guard was assumed to be on each site for 1 day per week for a year, patrolling the perimeter of the affected area and limiting entrance to authorized personnel only. The unit cost for population monitoring included a portable alpha survey, nasal smears, and two urine samples per person. An analysis cost of \$100/sample was used.

Unit costs for land reclamation were provided for lawn resodding, topsoil replacement, erosion control, and fertilizer plus seed. Lawn resodding included both material and labor cost; the cost of the sod (U.S. average - \$0.93/m^2) was approximately 99% of the total estimated unit cost. The unit cost for topsoil replacement also included a cost for materials and labor, with the materials making up about 82% of the total. The topsoil cost was \$5/yd^3 (\$6.50/m^3), and the unit cost assumed replacement of the top 2 in. (5 cm) of soil over an area of 1 km^2. The unit cost for erosion control included application of a cellulose slurry (\$200/acre or \$49,400 km^2) and soil stabilizer (\$125/acre or \$30,900/km^2). The material cost represented ∿50% of the estimated unit cost for erosion control, with the remainder being application costs. The unit cost for fertilizer plus seed was about \$200/acre (\$49,400/km^2). Labor for this unit cost was not added because it was assumed that this mixture could be applied at the same time as erosion control materials.

Unit costs for packaging and transportation of contaminated materials were derived from figures given in BNWL-2210(3) and by the Tri-State Motor Transit Company.(4) The cost of burial at a Federal repository was taken from (\$60/ft^3 or \$1.70/m^3) GESMO.(5) The transportation distance was considered as 1000 miles for the reference sites. Cost estimates were based on the following assumptions:

- The waste container was a DOT Specification 17C 55-gal (208-ℓ) steel drum. Fill volume was assumed to be 7.0 ft^3 (0.2 m^3) per drum (approximately 90% fill).
- Cost of 55-gal drum was assumed to be $20.
- Labor costs were based on $10.00 per man-hr and assumed 1 man-hr to fill and load a drum into a van (2 persons at 30 min/person).
- Hauling charges were calculated on the basis of $0.98/mile ($0.61/km) one way for the 1000-mile (1600-km) shipments).

BURDENING

All initial unit costs (see Table II.2, Section II) were burdened by overhead (25%), loss of efficiency due to protective clothing (30%), and workmen's compensation and social security (10%), except that the land reclamation cost did not include the 30% burden for protective clothing. The 25% burden for overhead took into account all supervisory personnel, equipment maintenance, and administrative costs. The 30% burden for protective clothing was based on loss of work time due to the necessity of suiting up and changing clothing several times per day.

SAMPLE UNIT COST CALCULATION

The procedure used in calculating unit cost can be best explained by example. The unit cost calculation for field sod removal is presented in Table D.3. Equipment needs (machine-days/km^2) were determined from equipment removal rates. Table D.4 presents the machine-days/km^2 for various pieces of decontamination equipment. One machine-day was equated to 8 machine-hr. Machine-days/km^2 were then multiplied by leasing costs (Table D.2) to determine equipment cost/km^2.

Crew requirements for the various decontamination operations are presented in Table D.4. For field sod removal, one machine operator and two laborers were assumed to work 138 days (Table D.3, pt. 2).

TABLE D.3. Unit Cost Determination for Field Sod Removal

			Cost
1)	**Equipment**	$\frac{138\text{ mach-day}}{\text{km}^2}\left(\frac{\$103}{\text{mach-day}}\right)$	$\$14{,}214/\text{km}^2$
2)	**Crew**		
	• Operator	$\frac{138\text{ mach-day}}{\text{km}^2}\left(\frac{1\text{ man-day}}{\text{mach-day}}\right)\left(\frac{\$86.80}{\text{man-day}}\right)$	$11{,}980/\text{km}^2$
	• Laborers	$\frac{138\text{ mach-day}}{\text{km}^2}\left(\frac{2\text{ man-day}}{\text{mach-day}}\right)\left(\frac{\$43.28}{\text{man-day}}\right)$	$11{,}945/\text{km}^2$
3)	**Support**		
	• Foreman	1 Foreman (70 Days) $\left(\frac{\$81.60}{\text{Foreman-day}}\right)$	$5{,}712/\text{km}^2$
	• Monitors	2 RM (70 days) $\left(\frac{\$60.48}{\text{RM-day}}\right)$	$8{,}467/\text{km}^2$
4)	**Supplies**		
	• Fuel	$\frac{0.53\text{ gal fuel}}{\text{hp-day}}\left(\frac{200\text{ hp}}{\text{mach}}\right)\left(\frac{138\text{ mach-day}}{\text{km}^2}\right)\left(\frac{\$0.428}{\text{gal}}\right)$	$6{,}260/\text{km}^2$
5)	**Equipment (Decon)**		
	• Laborers	2 mach $\left(\frac{1\text{ man-day}}{\text{mach}}\right)\left(\frac{\$43.28}{\text{man-day}}\right)$	$87/\text{km}^2$
	• Monitors	2 mach $\left(\frac{1\text{ man-day}}{\text{mach}}\right)\left(\frac{\$60.48}{\text{RM-day}}\right)$	$121/\text{km}^2$
6)	**Transportation**		
	• Equipment	$\frac{4\text{ trucks}}{\text{km}^2}$ (70 days) $\left(\frac{\$46}{\text{truck-day}}\right)$	$12{,}880/\text{km}^2$
	• Crew	$\frac{280\text{ truck-days}}{\text{km}^2}\left(\frac{1\text{ man-day}}{\text{truck-day}}\right)\left(\frac{\$86.80}{\text{man-day}}\right)$	$24{,}304/\text{km}^2$
	• Supplies (fuel)	(Determined as in Part 4)	$12{,}703/\text{km}^2$
	• Equipment (Decon)	(Determined as in Part 5)	$415/\text{km}^2$

TABLE D.3. Continued

7) Temporary Storage

• Equipment	$\frac{1\ \text{dozer}}{\text{km}^2}$ (70 days) $\frac{\$235}{\text{dozer-day}}$	16,450/kn^2
• Crew	$\frac{70\ \text{dozer-day}}{\text{km}^2}$ $\frac{1\ \text{man-day}}{\text{dozer-day}}$ $\frac{\$86.80}{\text{man-day}}$	6,076/km^2
• Supplies (Fuel)	(Determined as in Part 4)	5,081/km^2
• Equipment (Decon)	(Determined as in Part 5)	104/km^2
	TOTAL	\$137,000/km^2

TABLE D.4. Machine-Days and Crews Required to Clean Up 1 km^2

Equipment	Machine-Days/km^2	Crew Size
Harvesting-Chopping Machine (corn)	30	3
Harvesting-Chopping Machine (hay, soybeans)	6	3
Road Grader	70	3
Small Front-End Loader	625	3
Field Sod Machine	138	3
Lawn Sod Machine	625	2
Vacuumized Sweeper	21	1
Firehosing	163	3
Farm Tractor & Plow	8	1

For costing the removal equipment and its crews (Table D.3, pt. 1 and 2), the cleanup time did not need to be known specifically. However, time is typically a factor in costs for support personnel, equipment decontamination, transportation to a temporary storage site, and temporary site requirements. In the case of field sod removal, two machines were assumed available for removal, yielding a cleanup time of about 70 days/km^2.

Support crew costs (Table D.3, pt. 3) were based on one foreman per 50 persons and one radiation monitor per 5 persons, as discussed earlier. Supply costs for field sod removal (Table D.3, pt. 4) included the cost for diesel fuel. Fuel requirements were based on the following equation:(6)

$$\left(0.53 \ \frac{\text{gal fuel}}{\text{hp-day}}\right)\left(\frac{\text{hp}}{\text{machine}}\right)\left(\frac{\text{machine-day}}{\text{km}^2}\right)\left(\frac{\$0.428}{\text{gal}}\right) = \left(\$/\text{km}^2\right)$$

Machinery decontamination included the cost for cleanup of two machines and is shown in Table D.3, pt. 5.

For transportation of removed sod to a temporary storage site, four dump trucks per km^2 were considered available for hauling. Cost factors for transportation included equipment leasing, truck drivers, fuel supply, and equipment decontamination. Table D.3, pt. 6, shows the determination of these factors for the field sod removal unit cost.

Temporary storage site requirements involved the use of a bulldozer to pile removed sod. One bulldozer was considered for 1 km^2. The same cost factors were used here as for transportation; these are outlined in Table D.3, pt. 7.

By summing components 1-7 in Table D.3, the unburdened unit cost of \$137,000/km^2 for field sod removal was estimated.

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APPENDIX E

ECOLOGICAL IMPACTS

APPENDIX E

ECOLOGICAL IMPACTS

This appendix describes the ecological impacts that could be expected from application of the EPA Guidance to the assumed analyses. The application of measures that could be taken to prevent more extensive ecological damage is also assumed. Use of these measures is made in the calculation of costs for application of the Guidance.

Descriptions of three reference sites and the assumptions for decontamination were presented in Appendices A and C, respectively. In the three subsections below, the ecological effects of decontamination activities are briefly outlined for each site, according to the land types at the site and to alternative approaches to decontamination.

Note that ecological damage from transuranic contamination would be unlikely if no cleanup were undertaken. In order to have radioecological effects, it has been estimated that contamination would have to exceed 1 mCi/m^2.(1,2)

REFERENCE SITE ONE

Land areas assumed to be decontaminated at this site included corn fields, idle farmland, hay and soybean fields, pasture land, forest, residential area, and commercial area. The primary ecological effects would result from decontamination of the croplands.

The options for decontamination considered involved 1) removal of the top 2 in. (5 cm) of soil, 2) plowing to a depth of 10 in. (25 cm), and 3) plowing to a depth of 3 ft (1 m). For croplands, the first option would result in temporary minor effects, with only normal agronomic practices required before the land could be returned to use. Plowing of the area is one normal practice, therefore option 2 would result in no ecological effect. Option 3, plowing to a 1-m depth, would bring some subsoils to the surface, which could increase the concentration of salt or other plant toxins at rooting depths. The lower permeability of many subsoils might make leaching of salt difficult and result in the need for additional soil treatment to return the area to prime productivity. However, 1-m-depth plowing might result in a lower availability of plutonium because the contamination would be buried below rooting depths.

Overall, of all options for decontamination of croplands discussed, plowing to a 25-cm depth would have the least effect and plowing to 1-m depth the greatest. However, all effects would be temporary and easily mitigated by standard agronomic practices. If possible, decontamination should be scheduled so that fields could be available for planting in the spring.

The effects of decontamination on pasture lands would be similar to those on croplands. Removal of the top 5 cm of soil would require revegetation in the spring, following plowing and seed bed preparation. Options 2 and 3 would have results similar to those for cropland. In general, effects on pasture land would be of little consequence for this site.

Woodlot decontamination was assumed to require removal of the littermat. This would then have to be replaced with mulch and fertilizer to restore the nutrient supply and mitigate potential erosion problems.

Decontamination of population areas would have primarily socioeconomic rather than ecological effects.

In general, ecological effects associated with operations to clean up all land types would be minor and temporary. Care would need to be exercised in order that adjacent areas not be subject to excessive perturbation.

REFERENCE SITE TWO

Decontamination of this reference site was assumed to involve forest land, shoreline, and streams. Decontamination procedures were assumed to require removal of the forest mat using small front-end loaders and manual labor. An initial water stabilizer might be used on shorelines prior to the application of a long-term stabilizer. Soil removal was assumed to be accomplished by use of a road grader, manual labor, and a small front-end loader. Streams were considered to be monitored only.

Ecological effects associated with the decontamination of forested areas would be identical to those discussed for woodlots for Reference Site One. However, the overall impact would be less because less land is involved in this instance.

Decontamination of shorelines would impact aquatic life buried in the sand and perhaps birds nesting in the area. However, since the area is naturally disturbed by incoming tides, the impacts of decontamination would be of limited significance.

In general, all ecological effects would be of little consequence and would not affect the areas of concern to any substantial degree.

REFERENCE SITE THREE

Decontamination of this reference site would entail cleanup of pasture land, field crops, orchards, and irrigation ditches.

Impacts from the removal of the top 2 in. (5 cm) of soil at this site would be greater than those at the two sites above because soil types here are sandier and not as rich in nutrients. This condition would require additional soil treatment beyond that employed for the other reference sites. Revegetation should be initiated in the fall rather than the spring because the fall is the rainy season for this area. The site would require revegetation with nonnative grasses because there is a low probability that the area would recover to its original state and be productive as pasture land.

Plowing to 10-in. (25-cm) and 3-ft (1-m) depths would result in impacts similar to those at the Reference Site Two. However, revegetation would be inhibited since this area has less rainfall and poorer nutrient soil types. Agricultural land effects would be identical to those discussed for the Reference Site Two.

Ecological effects associated with orchards would result from the removal of the top 2 in. (5 cm) of soil (plowing was not considered), which might result in the loss of some trees. Many orchard trees are extremely shallow-rooted and could be seriously damaged by the machinery used.

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